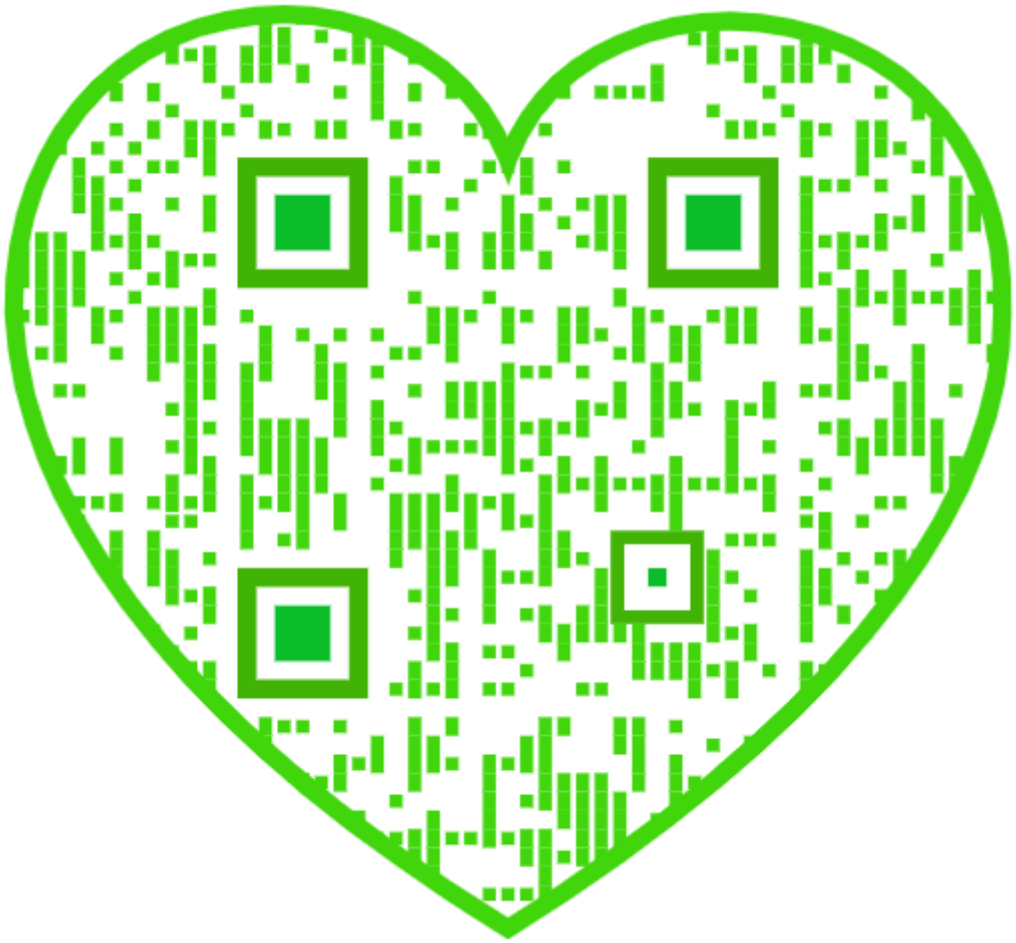

A TREATISE

ON

THE CONSTRUCTION AND OPERATION

OF

WOOD-WORKING MACHINES:

INCLUDING

A HISTORY OF THE ORIGIN AND PROGRESS OF THE MANUFACTURE OF WOOD-WORKING MACHINERY.

Illustrated by numerous Engravings,

SHOWING

THE MODERN PRACTICE OF PROMINENT ENGINEERS IN ENGLAND, FRANCE, AND AMERICA.

By J. RICHARDS,
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PREFACE.

In introducing this treatise on wood machines to the public, the Writer asks for its charitable consideration; and while he has no apologies to make for attempting to furnish such a work, he has many to offer for the lack of positive data which would have added to its value. His experience is that of a constructor of machines rather than of a writer of books, and but for the circumstance that no other work of the kind has appeared, such a task would not have been assumed. To write of an art that has passed through the hands of the scientific and the learned is a "dangerous thing," but when parallels and comparisons are wanting, and when there is a real and admitted need of such a treatise, it is comparatively safe. Shielding himself behind these conditions, the Writer would call attention to the fact that while every other branch of the industrial arts has been the subject of treatise upon treatise, scientific and practical, wood machines have never been considered.

The importance of the wood-working interest, in England and America, gives it a rank that should have claimed at least some place in our voluminous text-books, but not a line appears in them relating to the subject, if we except a brief part of Prof. Rankine's late work on machine tools, Molesworth's pamphlet on wood conversion, and Worssam on saws. Notwithstanding this, it is safe to assert that with their high speed and endless modification wood machines demand a higher grade of ingenuity and skill in their construction than machines for cutting and shaping metal. Accurate balancing, centrifugal force, the strength and arrangement of framing to resist vibration, and many other elements that belong to machine construction, have their

greatest importance in wood tools. It is easy to calculate the strain and provide for the proper performance of cutting tools moving at sixteen feet a minute, but when these cutting edges are moved *five to ten thousand* feet in the same time, a new set of conditions are involved, conditions that cannot be predicated upon the ordinary laws of construction, but have, with our present knowledge of the art, to be founded solely upon experience and observation.

The want of that scientific consideration to which wood machinery is so fully entitled, must in a great measure account for the imperfect manner in which much of it is made. In many, if not in the majority of the shops in America, there is no system of drawings, no standard for bearings, bolts, or shafting; the metal in the framing is disposed in the most unaccountable manner, in fact there is nothing approaching the standard of our machine tools, except the paint, which is laid on in "variegated profusion."

But it is outside the province of this work to criticize, inasmuch as it is not assumed to be a regular text-book. Yet it will not be amiss to "stir the matter up," and thus provoke the attention which the importance of this great interest demands.

As it was stated in the outset that no apology was needed for the introduction of this work, it is superfluous, for the same reasons, to apologize for its not being a text-book,—there is nothing to form a text-book from. The limited experience of one person can furnish but little material for such a work. If it is desired to prepare a treatise on the steam-engine or machine tools, or in fact on any of the common branches of mechanism, except wood machines, you have only to go to any scientific library, and the whole thing is before you,—rules, formulæ, drawings, repeated by a score of writers; but to write of wood machines there are no such data. Let this be a sufficient apology for what this treatise may lack, as compared with treatises devoted to other branches of engineering.

The plan adopted is to notice in a general way the several leading operations in wood conversion, with the construction and operation of the machines in modern use, introducing such rules, and treating of such laws as have been fixed by practice and experience, and have come within the knowledge of the Writer during an extended experience in designing and constructing both standard and special machines for wood work. It is to be regretted that during this experience, which was at all times divided with the charge of extensive manufacturing interests, no notes or memoranda were taken, as these would have been of invaluable assistance in the preparation of this treatise.

Special machines and adaptations, from the limits of the work, receive but little notice. Their consideration, to have any value, would require facts and statistics which, with the drawings needed to explain them, would have carried the extent of the treatise far beyond its plan.

It is, however, intended, if future interest seems to warrant it, to prepare a supplementary treatise on special machines for wood conversion, which shall include all of interest that is omitted here.

With these explanations, the work is submitted to the makers and users of wood-cutting machines, many of whom the Writer has the honour of knowing personally.

J. RICHARDS.

London, January, 1872.

ILLUSTRATIONS.

THE somewhat unusual plan of presenting regular shaded Engravings requires a word of explanation.

There is no excuse needed for the Engravings themselves, which are perhaps the most complete ever published in any work of this character. Not only are they complete in an artistic sense, but what is entirely unusual in such Engravings, they are mainly "true elevations" from geometrical drawings of the machines, so carried out, however, by shading, that they have the merit of pictures as well.

To have given instead Plates of true lineal Drawings would not have so well answered the purpose of the treatise. A restricted number only could have been used, and besides it would in that form have been of little value or interest to anyone but Engineers, and manufacturers of wood machines. In its present form it will have a value as well to those who *use* such machines.

A further objection to giving the usual Plans, Elevations, and Sections, in the present case, is that wood-working machinery is so fast undergoing modification and change, that even assuming that certain machines are sufficiently perfect to be presented for models, there is a want of confidence, a looking for something new, that would detract from their value, to say nothing of the brief time that they might represent the most improved construction. The Engravings given present, in most cases, ideas rather than definite plans, that is to say, the principles of operating, clothed in various forms and arrangements of mechanism.

From those who use, and practically operate wood machines, we must look for their improvement, rather than from the makers of the machines. Constructed of metal there is but little analogy between their manufacture and their after-use; and while all questions of proportion and arrangement belong properly to the Engineer, there

is a great deal that is obscure and peculiar in their operation. Hence it has been the object, as far as possible, to arrange the present work so as to have an interest both to those who make and those who use such machinery.

The Machines illustrated by the Engravings have been selected from houses that may be considered representative in the business, and from as few as possible, so as to comprehend the latest practice.

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XCIV.—Duplicating Machine .. .. *Ditto.*

XCV.—Ditto .. .. *Allen Ransome and Co.*

XCVI.—Moulding, Shaping, and Grooving Machine .. *F. Arbey.*

XCVII.—Wood Milling Machine .. .. *Ditto.*

XCVII.—Chamfering, Mortising, and Boring Machine .. *Allen Ransome and Co.*

XCVIII.—Machine for Straight Mouldings .. .. *Ditto.*

XCVIII.—Machine for Moulding and Shaping .. .. *Ditto.*

XCIX.—Machine for Making Wave Mouldings .. .. *Ditto.*

C.—Moulding and Shaping Machine .. .. .. *C. B. Rogers and Co.*

CI.—Combination Machine .. .. *Allen Ransome and Co.*

CII.—Ditto .. .. *Ditto.*

CIII.—Ditto .. .. *Ditto.*

CIV.—Ditto .. .. *Ditto.*

CV.—Ditto .. .. *Ditto.*

CVI.—Wood Cutting and Slicing Machine .. .. *F. Arbey.*

CVII.—Reciprocating Cutting Machine .. .. .. *Allen Ransome and Co.*

CVIII.—Veneer Cutting Machine .. .. *Ditto.*

CIX.—Jointing Machine .. .. *Ditto.*

CIX.—Reciprocating Cutting Machine .. .. .. *F. Arbey.*

CX.—Reciprocating Planing and Jointing Machine *Ditto.*

CXI.—Reciprocating Cutting Machine .. .. .. *Allen Ransome and Co.*

CXI.—Cutting and Paring Machine .. .. .. *Ditto.*

CXII.—Multi-Spindled Dovetailing Machine .. .. *Ditto.*

CXII.—Single-Spindle Dovetailing Machine .. .. *Ditto.*

CXIII.—Machine for Sharpening Saws .. .. .. *Ditto.*

CXIV.—Grinding Machine for Moulding-Irons .. .. *Ditto.*

CXIV.—Grinding Machine for Woodshops .. .. *Ditto.*

CXV.—Grinding Machine .. .. *S. A. Woods.*

CXVI.—Plan of Removing Shavings from Wood Factories .. .. *B. F. Stutevant.*

CXVII.—Automatic Lathe .. .. *B. D. Whitney.*

ERRATA.

The somewhat complex nature of the subject treated, the fact of its being quite new, and the absence of the author during the time the work has been in press, will, it is hoped, be a sufficient apology for the following errata:—

On Page 35, 9th line from the top, *for* "prefaced," *read* "prepared."
„ 45, 3rd line from the bottom, *for* "sawing," *read* "saving."
„ 55, top line, *for* "T. Arbey," *read* "F. Arbey."
„ 71, 16th line from top, *for* "spherical level," *read* "spherical seats."
„ 73, 14th line from bottom, *for* "five paces," *read* "five faces."
„ 73, 16th line from bottom, *for* "$W^3 = d$," *read* "$W = d^2$."
„ 78, 8th line from bottom, *for* "bobber metal," *read* "babbet metal."
„ 82, 10th line from bottom, *for* "remove," *read* "renew."
„ 82, 5th line from bottom, *for* "bobbet metal," *read* "babbet metal."
„ 83, 3rd line from top, *for* "girders," *read* "guides."
„ 99, top line, *for* "$\sqrt[3]{D + F}$," *read* "$\sqrt[2]{D + F}$."
„ 121, 2nd line from top, *for* "adopted," *read* "adapted."
„ 149, 5th line from top, *for* "12 inches deep or 92 inches wide," *read* "8 inches deep and 12 inches wide."
„ 149, 7th line from top, *for* "adoption," *read* "adaptation."
„ 159, 11th line from top, *for* "speed," *read* "feed."
„ 183, 2nd line from top, *for* "imperative," *read* "inoperative."
„ 193, 17th line from top, *for* "spores," *read* "spurs."
„ 215, 4th line from top, *for* "plane," *read* "plan."
„ 225, 3rd line from bottom, *for* "ship breaks," *read* "chip breaker."
„ 233, 14th line from bottom, *for* "screw," *read* "severe."
„ 246, *read* "arranged for moulding and planing."
„ 251, 12th line from bottom, *for* "machine planes," *read* "inclined planes."
„ 281, 5th line from bottom, *for* "distinction," *read* "destruction."

HISTORY OF WOOD-WORKING MACHINES.

INTRODUCTION.

It is not assumed to give all the facts connected with the origin of machines for cutting wood, as it would be impossible to gather them, except at an expense and trouble that there is nothing to justify. It is, however, safe to assume that, unless in some part anticipated by inventions in the Netherlands, the history here given as to the origin of what we will term the popular machines for planing, boring, sawing, and so on, is substantially correct.

With nearly all of the constructive arts we can trace their history back to a time when they were founded by the persevering efforts of a single person, some bold spirit, whose conceptions carried him beyond his age to meet and combat the scepticisms, if not the jeers and mockery, of those around him, and to find that in the words of the old poem—

> "A man is thought a knave or fool,
> Or bigot plotting crime,
> Who, for the advancement of his kind,
> Is wiser than his time."

The application of steam as a motive power came down to us through a number of inventors, each adding something left out by his predecessor, until the invention culminated in the labours of Watt and Trevithick. The first conceptions were crude, and gave no useful results beyond stimulating others to further efforts. A similar history attaches to engineering tools for cutting and shaping metals; and while the original idea of the use of power in such operations could no doubt, as said, be traced to a kind of fatherhood in some one person, no art seems to have been so fully developed, or so nearly perfected, at one time and by one man, as that of wood-cutting machines, by Sir Samuel Bentham, of England. In attempting to search into the history and origin of these machines, there can, perhaps, be no more appropriate Introduction than a personal notice of this remarkable

inventor. We say remarkable, for when we consider the crude mechanical manipulation of his time, and the poorness of resources that then existed, it would seem impossible to find anything to suggest, or even a want to justify his labours.

As Bentham's inventions constitute nearly all that was known of wood-cutting machines in the eighteenth century, their history at that period cannot be much else than an account of his labours and inventions, which, we are sorry to say, comes down to us only through his patents and scraps of history gathered from the record of the English dockyards, where his machines were first applied to public use.

Brigadier-General Samuel Bentham, Inspector-General of the naval works of England, received a thorough classical, and it is presumed, scientific education, at the Westminster School of London, which no doubt ranked high as an institution of learning at that time (1770). After completing his education, his predilection for naval affairs led him to his being bound to the master-shipwright of Woolwich Dockyard, where he served the regular apprenticeship of seven years, becoming familiar with all kinds of practical manipulation in wood and metal, and receiving the best scientific instruction that could then be obtained. After completing the term of his apprenticeship at Woolwich, he spent some eighteen months in visiting other dockyards, to familiarize himself with any local peculiarities of their tools and work that were not known at Woolwich.

In 1779 Bentham was directed by the Government to make a tour in the north of Europe to examine the progress of ship-building and other arts. During this tour, while in Russia, he invented the first *planing machine* for wood, at least the first that could be called an organized operating machine. There is no doubt but that this was the original conception of a machine for smoothing the surface and giving dimensions to wood.* It is to be regretted that no accurate descrip-

* We have ignored the machine of Hatton, patented in England in 1776, for the reason that it seems to have been an inoperating one, if it can be dignified by the name of machine at all.

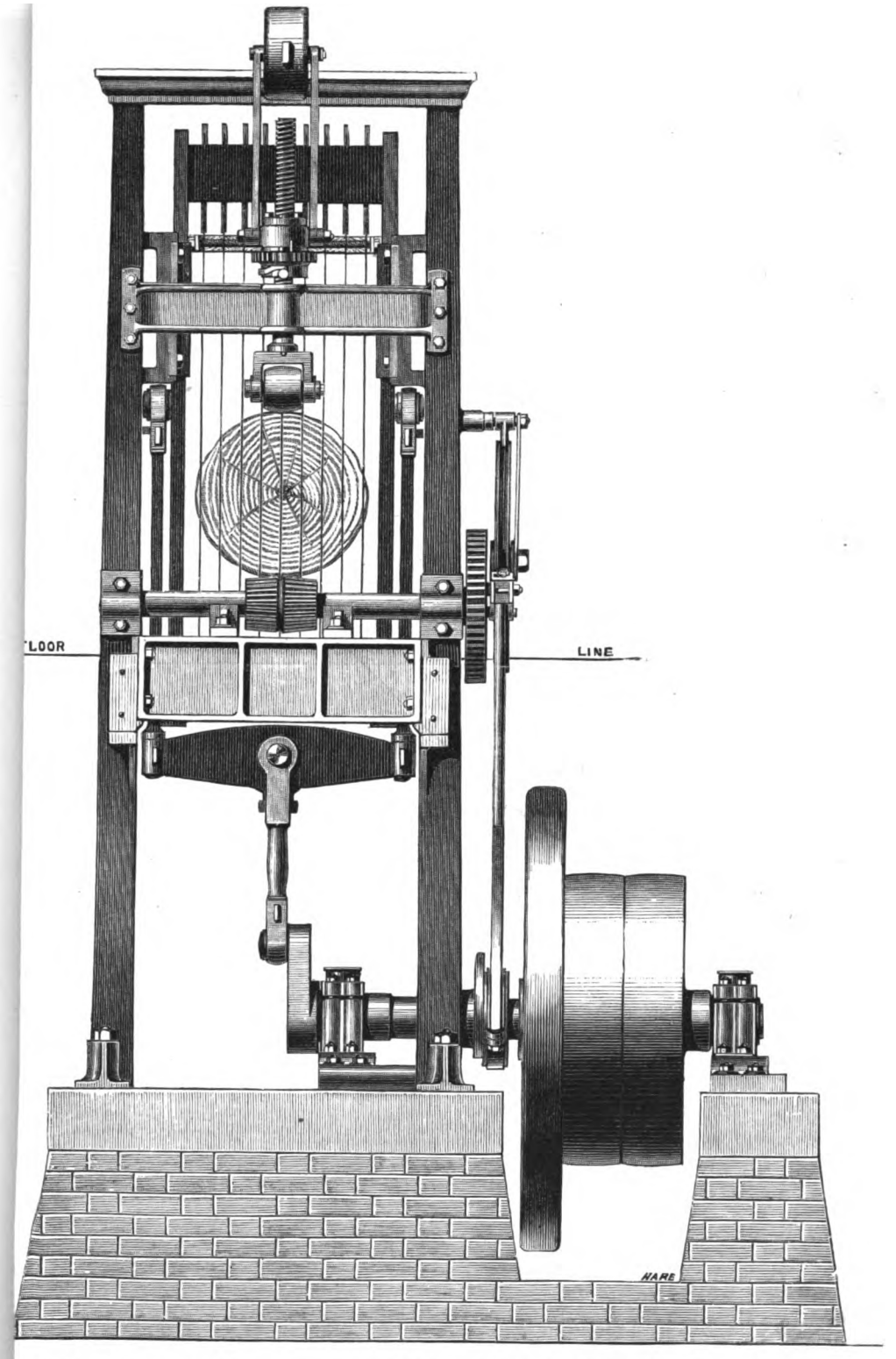
It appears to have been merely an idea for guiding planing cutters, by means other than the surface of the wood. Taking the drawing as an exponent of the invention, it has not been thought just to consider it as anticipating the invention of Bentham, who, if we are to judge by his other machines, would never have considered this as an operating machine for the purposes indicated.

tion of the invention, so far as perfected at that date, has been preserved. Whether it operated by what, in his subsequent patents, he terms "rotative" motion, or whether it was a reciprocating machine, is, so far as the author can learn, left to conjecture. It would, however, be inferred from his first patent in England, of 1791, that it worked upon the later principle, for "planing and making mouldings" by some means that bore a close analogy to the hand operations of the times, and corresponds to the one described in the patent cited. Bentham, with that regard for his country's interest that is common with all Englishmen, communicated his invention to the British Ambassador at St. Petersburg, who advised him to keep his invention for England, which seems to have been done, as there is no account of his having made any public use of it while in Russia. He afterwards accepted a military commission in Russia, with the rank of Lieutenant-Colonel, and became the manager, or commandant, of extensive factories for the production of glass, metals, cordage, works in wood, &c. His very successful management of these works would, from accounts, lead us to suppose that he invented many new and useful machines; but of these there seems (in England) to be no record. He returned to England in 1791, about which time his brother, Jeremy Bentham, the celebrated writer on political economy, had received from the Government an appointment to introduce industrial prisons in England. This kind of labour being almost devoid of skill, the talents of his brother were called into use to devise machines that would make the labour more profitable, and at the same time replace, to some extent, the want of skill of the convicts. To construct these machines, most of which were for working wood, the residence of Jeremy Bentham at Queen's Square Place, Westminster (now a part of London), was, with its capacious outhouses, converted into the *first manufactory* of wood-cutting machines. *Seventy-eight* years ago this factory was established, and, as we are informed, was not found to be sufficiently large, and a building, No. 19, York Street, was also occupied, which would lead us to suppose that a great many machines were made, and that the extent of the business fully entitles it to the distinction of being called the first general factory of such machines.

Professor Willis, in a lecture before the Society of Arts in 1852, states that "there were constructed machines for all general operations in wood-work, including planing, moulding, rebating, grooving, mortising, and sawing, both in coarse and fine work, in curved, winding, and transverse directions, shaping wood in complicated forms, and that further, as an example, that all parts of a highly-finished window-sash were prepared, also all the parts of an ornamental carriage-wheel were made, so that *nothing remained to be done by hand but to put the component parts together.*" These machines were examined by members of His Majesty's Administration, and received official notice and commendation in the House of Commons in 1794. Bentham (Sir Samuel) was next commissioned to visit different dockyards, and to determine how far his machines could be applied to facilitate ship-building. At this time he refused a flattering offer from the Emperor of Russia, in order to accept this commission, choosing rather to give his country the benefit of his services than to reap a greater pecuniary reward that awaited him in Russia.

His report was, no doubt, very favourable as to the employment of machines, but it was not until 1797 that the Admiralty consented to their introduction. It should have been mentioned that during the time of his manufacture of machines at Westminster and York Street, patents were taken out describing all the different operations performed. After the Admiralty deciding to adopt his machines in 1797, they were manufactured under the direction of Jeremy Bentham, and forwarded from time to time to Portsmouth and Plymouth, where they performed, so far as any record shows, all that was claimed for them.

The bills specify lathes, saws, machines for cutting, tenons for boring, also for boring bitts and squaring tools, "and many other machines for different kinds of work." Machines were also devised by Bentham to facilitate block making, an operation that is yet classed among the most difficult. His machines, however, for this purpose did not seem to be perfect, for in 1810 he was joined by Brunel, who had invented a machine for "shaping block shells." Brunel was at that time employed under Bentham to assist in the various operations, and to perfect his own machine, which must have



Weight—From 8 to 15 tons. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

had the endorsement of Bentham. In 1803 Sir Samuel, as Inspector-General, advised the Admiralty to adopt many additional machines that had already been approved, and to permit the erection of steam-engines to drive them, and they were accordingly ordered. The several dockyards were fitted with engines for sawing, planing, boring, tenoning, mortising, &c., and apart from better construction and the greater experience in their use, it is fair to infer they had nearly all the functions found in modern machines for these purposes. Their labour-saving capacity is sufficiently attested by the fact that Brunel, who had perfected and assisted in their construction and operation, was rewarded by being allowed, as a premium for his inventions, the estimated savings of one year's work over hand-labour in the dockyards, which amounted, as we are informed, to the very large sum of 16,000*l.*

In 1813 arbitrators were appointed on the part of the Government to settle with Jeremy Bentham, who, after the examination of numerous witnesses, allowed him the sum of 20,000*l.* for machines furnished to the dockyards and penitentiaries. From the testimony given before this commission we learn that "Sir Samuel Bentham prepared a system of machinery for the employment of men without skill, and particularly with a view to utilizing convict labour. In 1793 patents were taken out on these inventions to secure their exclusive use for the prisons. The testimony states that no skill was required in the use of these machines; they were introduced into the dockyards, and worked by common labourers." The use of the machines saved *nine-tenths* of the labour. "A table could be made at one-half the expense by their use," &c., &c., which goes to show that the machines were at least effective; a claim that cannot in many cases be made for those of more modern manufacture.

The machines and appliances for working wood that were invented and practically applied by Sir Samuel Bentham previous to the year 1800 may be enumerated as follows:—

Machine for planing and forming mouldings—Improved planing and moulding machine (rotary)—Wedging guard for circular saws—Segmental circular saw—Conical cutters for dovetail grooves—

Undulating carriage, to form wave mouldings—Compound cutter heads to work two or more sides at once—The *slide rest*—Tubular boring implements (core boring)—Crown saws (or cylinder saws)—Reciprocating mortise machine—Rotary mortising machine—Radius arm for sawing segments—Tracer guide for sawing irregular forms—Bevil and curvilinear sawing—Machine for grinding saw-blades—Taper gauge for sawing—Grooving table—Vertical adjustment of saws in benches—T rebating machine—Sectional cutters—Pivoted table for mortise machines—Forked or double mortise chisels—Gauge lathe, with slide rest—Rotary cutters for forming screw threads on wooden screws—Double grooving saws—Rack feed for planing machines—With many other things.

The slide rest for turning is very fully and clearly described in Bentham's patent of 1793, and it ranks with the greatest as an invention in engineering implements. It gave us the engine lathe, without which our modern practice in machine fitting could not be carried on.

The facts adduced will be sufficient to show that Sir Samuel Bentham is entitled to the distinction of being called the "Father of wood-working machines" in England, at a date that precludes any probability of his inventions having been anticipated in other countries. Let us not forget in looking back over this history, surrounded as we are by the more perfect art, the circumstances under which these machines were made. Imagine "catgut" bands and grooved pulleys for transmitting rapid motion, the want of skill in the workmen to carry out his designs, the want of all our modern machines, except the hand-lathe, to shape metals, the imperfect knowledge of geometrical drawing that then prevailed, the ignorance, in short, of nearly all the appliances with which we are familiar, and now consider indispensable.

We must not, however, regard the construction of the machines so remarkable, as the wonderful genius displayed in the invention of the *processes*, apart from the machines themselves.

In the proceedings of a trial between the Crown and James Smith in 1848, for the repeal of a patent on sawing machinery,

reported in the 'Mechanic's Magazine,' there is appended a note that pays a tribute to the genius of Bentham greater than all the honours conferred on him by the Government during his life, from which we will quote as follows:—

"Sir Samuel Bentham was the first to introduce saw-mills into our national arsenals, the first also to lay down the principles of all kinds of machine saws that may be constructed, and which have never since been materially departed from. The specification of his patent of 1793 is a perfect treatise on the subject, *indeed the only one worth quoting that has to this day been written on the subject.*"

To show the acquaintance of Bentham with the laws of force and motion, and more especially to show his style of reasoning and his plan of deduction, we will quote from his specification of 1791.

Speaking of motive agents, he says:—

"By brute force I mean not only the strength of animals, but the force of inanimate objects, and even that of men, when employed in such a way as to require neither skill nor dexterity on the part of the person who executes it. By this means machines may take the place of human skill in this operation (planing) to as perfect a degree as in any of the manufactures, on which invention has been employed so much to the honour and advantage of our country. Hence three capital advantages. *First*, the quantity of force used at one time can be increased at pleasure. *Second*, the force of men may in this way be exerted to a greater advantage than while confined as in present practice to the particular mode, by the necessity of care and dexterity. *Third*, the labour of the awkward and unpractised may be used," &c.

Although his name has not been enrolled in the highest place of mechanical fame, accorded a second, or even a third place, yet it might be safely asserted that Sir Samuel Bentham gave to the world more useful inventions than any man of his age: it might even be claimed that he has done so, leaving out the circumstances of time and conditions; but when we take these into consideration, and the value of such inventions at the first dawn of development of mechanic art in England, the proposition is reduced to a certainty. The inven-

tions extended over the entire range of useful art; manufactures of all kinds received his attention, and were all more or less indebted to his genius. Throughout the whole there can be traced a constant method, and a system of deductive reasoning, that indicate rather a life of labour, qualified by scientific learning, than one of what the world would term "genius."

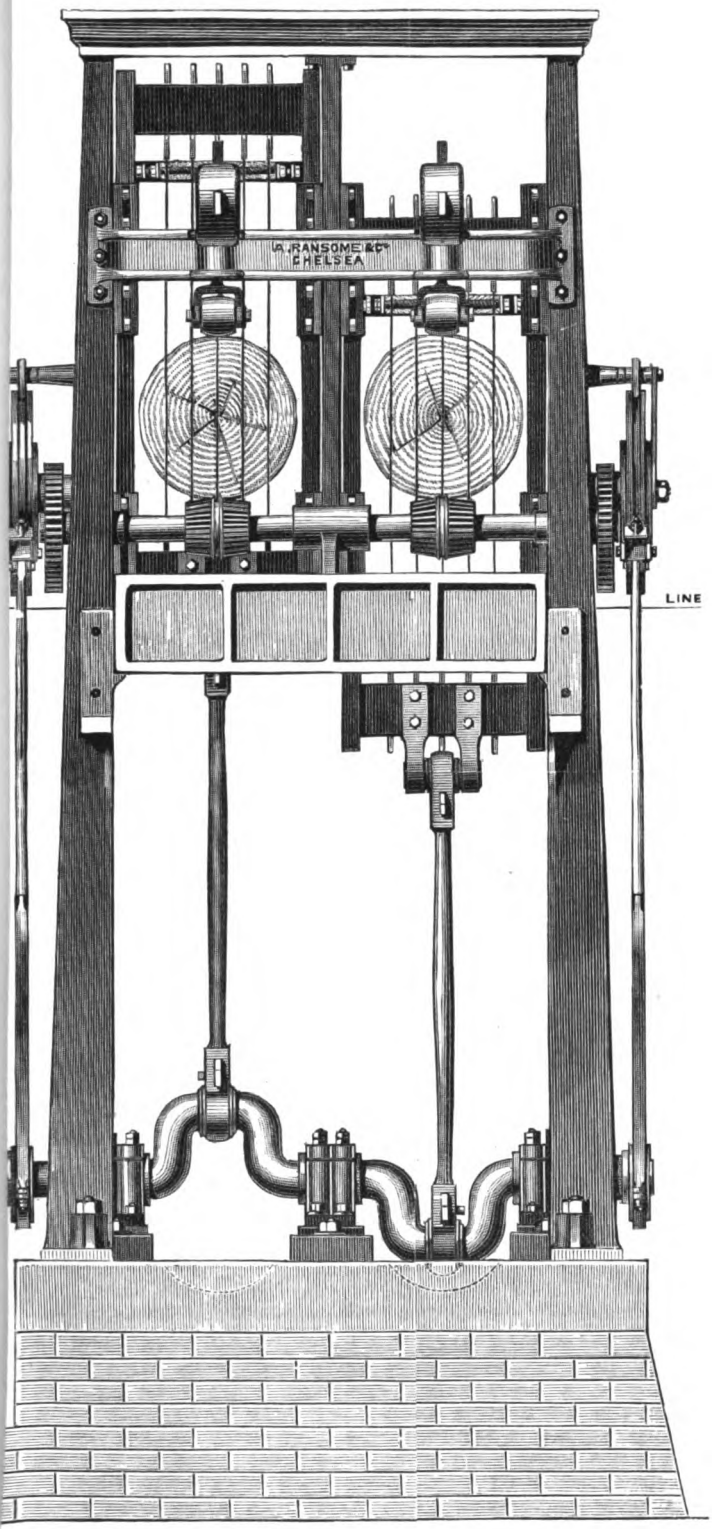
Genius he must have had in the highest degree, for granting him all the attributes of a great and learned engineer in their greatest scope, there still seems to be much wanting for the accomplishment of so great a work.

Had the talents and genius of Bentham been directed in the field of letters or science alone, a niche in the Abbey would perpetuate his fame; but in that silent field of equal importance at least, the practical development of the useful arts, he was not brought in contact with the powers that manufacture fame. Yet his is a noble lot, enshrined as he is in the admiration and grateful remembrance of engineers, who must ever accord to him the very first place as a legitimate inventor.

Having traced the origin of nearly all kinds of wood-cutting machines to Bentham, it would nevertheless be unfair to deny to others their share in the matter. We will therefore notice some of the machines invented during the first ten years of the nineteenth century, which can with propriety be termed the first, the beginning of the art.

The planing machine of Hatton, mentioned in the paper of Molesworth, cannot in justice to Bentham, as already noticed, be regarded as the pioneer of its class.

The patent of Miller for a sawing machine, granted in 1777, is deserving of notice, as containing nearly all the elements of the modern American circular-saw mill, except the propelling power. The specification being short and "quaint," it is inserted in full, as containing in the fewest words a comprehensive description of the machine.



—From 5 to 11 tons. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

"British patent, No. 1152.

"To SAMUEL MILLER, of Southampton,

"Sail maker, &c., &c.

"NOW KNOW YE, that, in compliance with the said proviso, I, the said Samuel Miller, do hereby declare that my said invention, of an entirely new machine for the more expeditiously sawing all kinds of wood, stone, and ivory, is described in the manner following (that is to say) :—

"The machine that gives the power, a horizontal windmill. The shaft of this mill stands vertical, with four levers fixed to it at right angles with the shaft, to which levers are fixed the sails. These sails when in motion are one-half of their time horizontal, the other vertical. The upright shaft being in motion, communicates its power to a horizontal shaft. This shaft hath a large wheel to it, round which goes a rope or chain, which is continued to a smaller; through the small wheel goes a square bar of iron, that receives the saws, *which are a circular figure.* Those saws being in motion, the matter or substance they are to cut is brought forward as follows:—The horizontal shaft, as mentioned before, hath a small wheel on it, with a groove to receive a rope; the rope is continued to a smaller, that hath a pinion to it, connected to a straight bar under the chariot, which hath teeth to match the pinion ; the chariot moves in a groove likewise on a centre ; it hath two motions, one to advance forward, and the other sideways, which is performed by a screw annexed to the end of the chariot. This screw is turned by hand to direct the pieces against the saws, agreeable to any line wanted to be cut.

"In witness whereof, I, the said Samuel Miller, have hereunto set my hand and seal, this Fifth day of August, One thousand seven hundred and seventy-seven.

(Signed) "SAMUEL MILLER." (L. S.)

There is no doubt but that this patent, now *ninety-four years old,* indicates the first that was known of circular saws in England, and as such is entitled to no small share of interest as an invention. This

machine of Miller's was a fully-organized sawing machine, fitted with a carriage, having a compound movement, and, to use the modern terms of English makers, a "rack bench," with lateral adjustment. We must, however, conclude that Mr. Miller used undoubtedly the most appropriate and comprehensive name, "sawing machine," instead of "bench," which technically should convey an idea of something quite different.

Passing next over the patents of Sir Samuel Bentham of 1791 and 1793, we come to that of Joseph Bramah of 1802.

Taking into consideration the nature and scope of this patent, with its early date, and considering the subsequent history of wood machines, it is safe to say that, with one exception, it was the most important invention made during a term of forty years: the exception is the invention of the duplicating machine by Boyd, of America, for turning irregular forms, which will in its turn be noticed. The portion of this patent of Bramah that relates to planing was the origin of what may be termed "transverse" or "traverse" planing machines, a type that to this day, with but little modification of his plans, is found in nearly all large factories for working wood, and in dockyards generally.

The description contained in the specification is so clear, that we can do no better than use the words of the inventor, in which he declares the principles and objects of his invention are:—

"To shorten and reduce manual labour, and the consequent expenses which attend it, by producing the effects stated in my patent by the use of machinery, which may be worked by animal, elementary, or manual force, and which said effects are to produce straight, true, smooth, and paralleled surfaces, in the preparation of all the component parts of work, consisting of wood, ivory, horn, stone, metals, or any other sort of materials or composition usually prepared, and render it true and fit for use by means of edge-tools of every description. I do not rest the merits of this my said invention on any novelty in the general principle of the machinery I employ, because the public benefit I propose will rather depend on new effects produced by a new application of principles already known, and

machinery already in use for other purposes in various branches of British manufacture. This machinery and the new manner of using it, with some improvements in the construction, together with sundry tools and appendages never in use before, are particularly described and explained hereunder. I mean to use and apply for the purposes above stated every kind of edge-tool or cutter already known, either in their present shape, or with such variations and improvements as the variety of operations I may encounter may severally call for. But the tools, instead of being applied by hand as usual, I fix, as judgment may direct, on frames drove by machinery, some of which frames I move in a rotary direction round an upright shaft, and others having their shaft lying in a horizontal position, like a common lathe for turning wood, &c. In other instances, I fix these tools, cutters, &c., on frames which slide in stationed grooves, or otherwise, and like the former, calculated for connection with, and to be driven by machinery, all of which are hereafter further explained and particularized. The principal points on which the merits of the invention rest are the following :—

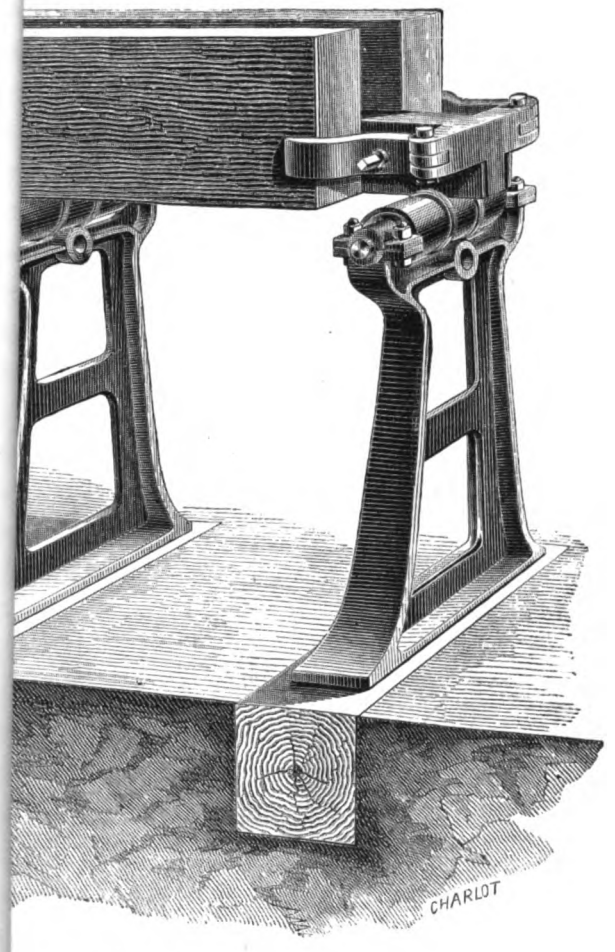
"First. I cause the materials meant to be wrought true and perfect, as above described, to slide into contact with the tool, instead of the tool being carried by the hand over the work in the usual way.

"Secondly. I make the tool, of whatsoever cutting kind it be, to traverse across the work in a square or oblique direction, except in some cases where it may be necessary to fix the tool or cutter in an immovable station, and cause the work to fall in contact with it by a motion confining it to do so, similar to the operations performed on a drawing bench.

"Thirdly. In some cases I use, instead of common saws, axes, planes, chisels, and other instruments usually applied by hand, cutters, knives, shaves, planes, and the like, variously, as the nature of the work may render necessary, some in form of bent knives, spoke-shaves, or deep-cutting gauges, similar to those used by turners for cutting off the roughest part. I also apply planes of various shapes and construction, as the work may require, to follow the former in succession under the same operation, and which latter I call finishers.

"Fourthly. The cutters, knives, &c., I fix on frames of wood or metal, properly contrived for their reception, and from which they may easily be detached for the purpose of sharping and the like. These I call cutter-frames. These cutter-frames I move in cases like those on which the saws are fixed in a sawing mill, and sometimes to reciprocate in a horizontal direction, confined and stationed by grooves or otherwise, as may be found best calculated to answer the several works intended. In other instances, and which I apprehend will generally have the preference, I fix cutter-frames on a rotary upright shaft, turning on a step, and carrying the frame round in a direction similar to the upper mill-stone; and sometimes I cause the frames to turn on a horizontal shaft just resembling the mandrel of a common turning lathe, or those machines used for cutting logwood, &c., for the dyers' uses. When these frames are mounted in any of the foregoing directions for cutters, planes, &c., are fixed so as to fall successionally in contact with the wood or other materials to be cut, so that the cutter or tool calculated to take the rough and hilly part operates the first, and that those that follow must be so regulated as to reduce the material down to the line intended for the surface. These cutter-frames must also have the property of being regulated by a screw or otherwise, so as to approach nearer the work, or recede at pleasure, in order that a deeper or shallower cut may be taken at discretion, or that the machine may repeat its action without raising or depressing the materials on which they act. The manner of thus regulating the cutter-frames when on an upright shaft is particularly described below. These cutter-frames may be made of any magnitude and dimensions the work requires, only observing to make the diameter of those on a rotary plane so as to exceed twice the width of the materials to be cut, as the said materials must slide so as to pass the shaft on which the cutter-frame revolves when on the upright principle."

Comprehended in this patent, and described at great length and exactness by the inventor, is the liquid bearing for stepping vertical shafts. The subject also of a "very recent invention," that came under our notice.



d.

Bramah, however, not only invented the liquid bearing, but went further. He performed the vertical adjustment of his cutter spindles by the same means, pumping in the liquid at will, and securing a very precise, as well as positive, setting of his machine. This mode of adjustment does not seem to have occurred to the modern inventor, and the "hydrostatic adjustment," which has so many parallels in modern practice, may, for all the author knows, owe its origin to this device of Bramah's, but whether it does or not, the originality of the thing with him cannot be questioned. In his time engineering discoveries and engineering knowledge were not heralded through the world as fast as known, and we must, in order to be even impartial, give these old inventions the benefit of all doubts that may arise as to their originality.

Another still more important feature of this invention was what we term conical gearing for varying motion, now extensively employed in modern engineering practice for regulating the feeding mechanism of lathes and other metal-cutting machines, as well as in wood machines.

The description is so quaint and ingenious, that there needs no apology for inserting it here in full; a little allowance can, however, be suggested, as to the maximum speed suggested by a compounding of these cones of wheels, as described by the inventor.

In speaking of the carriage movement, he says:—

"I regulate the motions of both these parts of the apparatus, as before mentioned, by means of a new invention, which I call an universal regulator of velocity, and which is composed as follows, *viz.* I take any number of cog-wheels of different diameters, with teeth that will exactly fit each other through the whole, suppose ten, or any other number, but for an example say ten, the smallest of which shall not exceed one inch in diameter, and the largest suppose ten inches in diameter, from one to ten. I fix these ten wheels fast and immovable on an axis perfectly true, so as to form a cone of wheels. I then take ten other wheels, exactly the same in all respects as the former, and fix them on another axis, also perfectly true, and the wheels in conical graduation also; but these latter wheels I do not fix fast on their axes like the former, which are fixed. All those latter

wheels I have the power of locking by a pin or otherwise, so that I can at discretion lock or set fast any single wheel at pleasure. I then place the two axes parallel to each other, with the wheels which form the two cones, as above described, in reverse position, so that the large wheel at the one end of the cone may lock its teeth into the smallest one in the cone opposite, and likewise *vice versâ*. Then suppose the axis on which the wheels are permanently fixed to be turned about, all the wheels on the other axis will be carried round with an equal velocity with the former, but their axes will not move. Then lock the largest wheel on the loose axis, and by turning about the fast axis as before, it must make ten revolutions while the opposite performs but one; then, by unlocking the largest wheel, and locking the smallest one at the contrary end of the cone in its stead, and turning as before, the fast axis will then turn, the opposite ten times while itself only revolves once. Thus the axis or shaft of these cones or conical combination of wheels may turn each other reciprocally as one to ten and as ten to one, which collectively produces a change in velocity under an uniform action of the 'primum mobile,' as ten to a hundred, for when the small wheel on the loose axis is locked, and the fast one makes ten revolutions, the former will make one hundred. And by adding to the number of those wheels, and extending the cones, which may be done *ad infinitum*, velocity may be likewise infinitely varied by this simple contrivance. A may turn B with a speed equal to thousands or millions of times its own motion; and by changing a pin and locking a different wheel, as above directed, B will turn A in the same proportion; and their power will be transferred to each in proportion as their velocities reciprocate. Here is, then, an universal regulator at once for both power and velocity. In some instances I produce a like effect by the same necessary number of wheels made to correspond in conical order, but instead of being all constantly mounted on the axes or shafts as above described, they will be reciprocally changed from one axis to the other in single pairs, matched according to the speed or power wanted, just as in the former instance. This method will have in all respects the same effect, but not so convenient as when the wheels are all fixed," &c.

In 1808, four years later, there was granted to William Newberry, of London, a patent for a machine of which a correct illustration is shown among the engravings. The title is that of a machine for sawing wood, splitting and paring skins, &c. Supposing this to be the origin of the practical band-saws, which, from the want of any facts to the contrary, we will assume; it was a remarkable invention, not perhaps so much for the idea of an endless saw-blade, but for the fact that a machine, so perfect and operative as a whole, should be built and then lie dormant for a period of forty years.

It is easy to imagine the hopes and expectations that agitated the mind of the inventor of a thing that gave promise, as this must have done, of becoming at once the greatest of inventions; supplanting all other methods of sawing, as well as giving a continuous movement to cutting edges for paring, slitting, &c. Nor was the inventor wrong in such hopes, even if he entertained them; but little did he think that it would require more than two generations to develop a thing apparently so simple. Such, however, was or is the fact, for we are just now demonstrating the capacity and adaptation of the band-saw; a matter that will be spoken of under its proper head.

The details on the left of the engraving show the inventor to have not only conceived the idea of a band-saw, but to have considered very fully its application. The feeding rolls and radial guide are very much as now constructed, and sufficiently complete for the uses intended.

The pivotal table, having its fulcrum in the plane of the top, is a thing which most builders regard as a modern improvement.

Disregarding the trouble that would occur in removing and replacing the saw-blade, the machine is good and operative; and as the drawing is only from a model, we can hardly claim to have made, during sixty years past, so great an improvement in band-saws as should naturally follow if compared with other machines.

The patents of Brunel, of 1805–8, relating to the construction and operation of saws, serve rather to show the gradual growth of knowledge in the art than any important discovery.

We now come to the patent of Boyd or Blemchase of 1822, con-

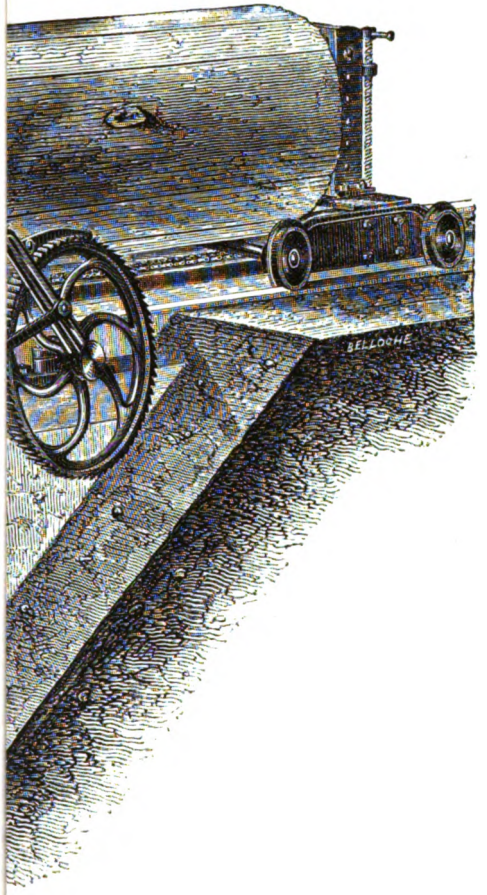
taining the generic idea of all machines for duplicating forms in wood, as well as in other materials. So clearly defined is the principle or mode of operating, that the Courts, in the many cases of litigation that arose over this patent, never failed to see, nor lay down in their decisions, this principle of duplication. Neither the machine that forms the particular subject of the patent, nor the specification itself, need be reverted to here, as, in the after-history of the patent, special mechanism was entirely lost sight of. The idea was that of using a model in conjunction with a blank, the outline of the model guiding the cutting tool to produce a duplicate from the blank.

Its first application, the one described or shown in the specification, is to a shoe-last, a piece of the most irregular outline, and yet produced perfectly in this duplicating machine.

This invention was what may be termed an original one, in the sense of not being an improvement. No analogous operation had ever been carried on, either in wood or other material; and instead of being a machine, or being considered as a machine, it must be looked upon as the beginning of a system from which has sprung hundreds of modifications, all sufficiently distinct to be called machines, and yet all operating on the principle of the original invention. Our modern Courts define "principle" in mechanics as meaning a mode of action, and hold that principles are not patentable; a rule that it would certainly trouble them to apply in the case of this patent, which related to a "mode of operating" beyond doubt. This patent, like that of Woodworth's for planing machines, hereafter noticed, was the subject of long and bitter controversies in the United States, where the incentives to its infringement were very great, owing to large profits arising from its application to making lasts, axe-helves, gun-stocks, and other irregular forms that were expensive to make by hand.

The patent was twice extended, and only expired some five years since in America.

It was finally construed as covering all kinds of duplicating machines working from models, a rendering that the public consented to finally, and it was no doubt just, although clashing a little with the letter of the law, as before intimated.


BELLOCHE

It is useless to here follow out the various machines tributary to this patent, as they will be noticed under their proper heads in the chapters relating to machines and functions.

From about the year 1815 to the Universal Exhibition of London in 1851, the manufacture of wood-working machines, in England, remained but a limited business, and no advance was made that at all compared with what was effected in other branches of engineering. Many machines for special uses were no doubt made and used that combined both skill and ingenuity, but upon the whole wood machines may be said to have laid dormant in England for a period of forty years.

This is the more astonishing when we reflect that during this time the great revolution, not to say the "origin," of engineering implements took place. Sir Joseph Whitworth, during this time, perfected his system of metal cutting and shaping machines, which have not since, and perhaps in future will not be, materially changed. Great inventions and scientific discoveries had been made, and wood machines seemed alone to be neglected.

In 1844, some years previous to the Exhibition, Wm. Furness, of Liverpool, imported from the United States, and patented in England, most of the machines then made by C. B. Rogers and Co., of Norwich, America. The ruling idea in these machines was economy in cost and rapid performance in the hands of skilled men, neither of which elements fitted them for the English market at that time; consequently no great use seems to have been made of the plans and modifications that they might have suggested to builders in England.

During the Exhibition of 1851, however, the performance of the "wood framed" American machines was such as to create astonishment. English engineers at once proceeded to clothe the "ideas" these machines suggested in a mechanism more in keeping with their purpose and the true principles of machine construction, and out of it grew, as we may say, a large share of modern practice in England.

In following the history of wood machines, it might be said that, from 1835 to 1852, the development of the art was transferred from the old to the new world. The American people, without iron, or the

means of adapting it to the many uses to which it was already applied in England, adopted instead the wood of their forests, applying it to all conceivable uses in the construction of buildings, ships, machines, roads, and the framing of steam-engines, for which purpose it is even yet, to a large extent, used. Necessity, which has been termed the mother of invention, coupled with a strong ingenuity and boldness of plan that has always characterized the Americans, led to a rapid development of an entire new system of wood machines for sawing, planing, boring, mortising, tenoning, &c., besides hundreds of modifications of special machines adapted to the manufacture of carriages, ploughs, furniture, joiners' work, bent work, &c.

Prominent among the inventions introduced was what is known as the "Woodworth planing" machines. This notorious monopoly lasted, by regular extension and act of Congress, over a period of twenty-eight years, costing many thousands of dollars in some *sixty-four* suits at law which followed, crippling the interests of the country to the extent of millions of dollars, to say nothing of the many inventions in rotary cutting machines that would have been developed had this monopoly been removed. We say monopoly, for the patent of Woodworth was never accepted as a *bonâ fide* invention, with the scope at least that the interpretation of the Courts gave it. There need be no further evidence of this given than the numerous appeals in the face of former decisions. It is true that many of these suits were in "equity," and did not involve directly the question of validity of the patent, but they nevertheless, in nearly every instance, showed that public opinion did not acquiesce in the decisions on this point. In explanation and support of the opinion expressed, it must be admitted that the combination of rotary cutting cylinders and feeding rolls would, in the natural development of this art, have soon followed as a matter of course, and that as soon as lumber dressing by power was an industrial necessity, this combination would have been invented, not by a single man only, but by a majority of as many as would attempt to build planing machines: in other words, the *planer was a sequence of the state of the art*, and the art was not dependent on the invention of Woodworth.

Cutting cylinders for wood were, under several modifications, known, as we have shown in a former place, thirty-five years before. In 1811 a patent was granted to Charles Hammond, of the City of London, for improvements in machinery for sawing and planing wood, in which he fully describes the use of feeding rolls for passing lumber to circular and other saws. Similar feeding rolls were used for analogous purposes in other machines, and when it became necessary to move a board continuously under a rotary cutting cylinder, the public would not have had long to wait for the mechanical devices forming the subject of Woodworth's specification. In fact, planing flexible lumber to a parallel thickness was quite a new thing, and at variance with the established plans of planing wood. In America, however, the lumber is cut into thin boards in the forest, and is apt to spring or become crooked in drying; hence the importance of a roller feeding planer for flexible stuff, a thing not before needed, and which to this day has never become a machine of much importance, except in the United States, where this system of lumber-traffic prevails.

It is not the intention of the writer to disparage the invention of Woodworth, and he begs to present these views of this old patent as coming from a practical mechanic, himself a patentee of improvements in wood machines, and as the frank expression of an opinion based upon an impartial consideration of the facts.

Since 1850 the inventions in wood machines have followed each other in rapid succession in America. The most complicated forms in wood of regular or irregular outline are produced at a cost, and with a degree of accuracy, which cannot be attained by hand manipulation. Engineers and inventors, in both Europe and America, during two or three years, have been giving to wood machines such attention as they demand and the wants of the market have forced out. Within the past two years the art has been raised to the dignity of recognition among other branches of engineering; the scientific journals of England have given more space to wood machines than for the previous ten or even twenty years; and regular engineering establishments are springing up in England, America, and on the

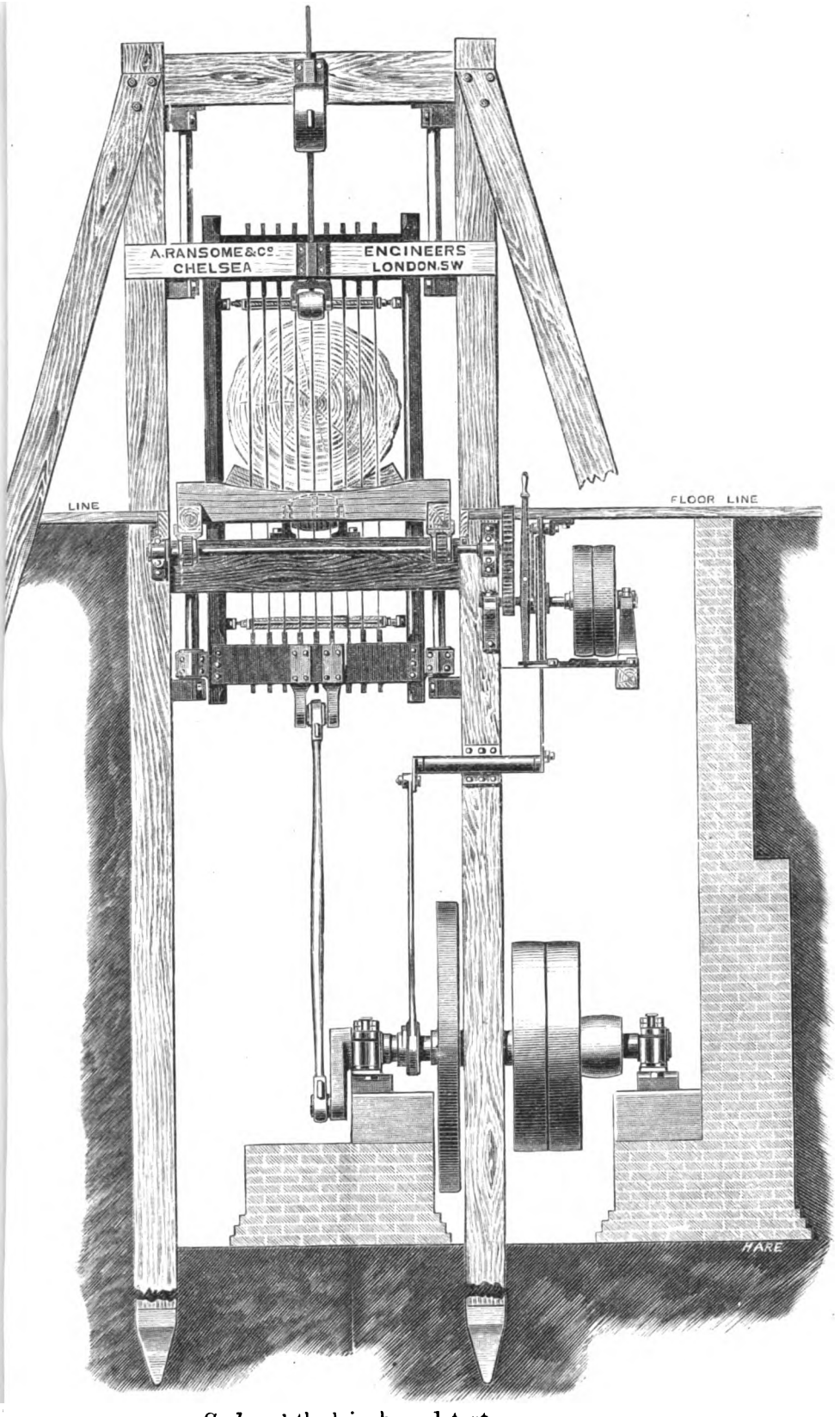
Continent, which give their attention to wood-working machines as a specialty.

Offering an apology for this very brief recital of what we consider the leading facts in the rise and progress of this art, we feel that the book would have been incomplete without it. The facilities for gathering facts of this kind are quite limited, especially when we consider that wood-cutting machines have grown up with civilization in all countries, and have not, like many other things, been developed in one place.

The early history of wood machines in the Netherlands would no doubt add many facts of interest, but as the manufacture of such machinery is now chiefly carried on in England, America, France, and Northern Germany, the interest in its history must be confined to its development in these countries.

What was done in this manufacture previous to twenty years ago is a matter of but little interest, except as one of curiosity. We have no practical use for such knowledge now, unless it is to protect the public from "re-invented machines," an interest that is by no means so unimportant as it would at first seem, for patent monopoly tax is paid to the extent of thousands of pounds annually on things that of right belong to the public, and the only defence against these monopolies is to adduce these old facts to establish that right.

The history of Bentham's inventions in wood-cutting machines brings to mind the facetious remark of a great writer when accused of plagiarism from Homer. He examined the book and found the charge justified, when he exclaimed, "These thieving ancients have stolen all of our modern ideas."



to 8 tons.

Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ENGINEERING PROGRESS.

The estimate of a people's civilization is based, in a popular way, upon what they know of useful art. That other standards are better, or that the one indicated is unfair, is a question with which we have not to deal; the fact remains, and certainly not without some adequate reason. When we inquire as to the scale of knowledge in any country, or with any people, we do not first ask what is their religion, or what is their philosophy, but we inquire whether they can "weave cloth" and "forge iron;" whether they have learned to control the natural forces and directed them to the performance of that which must otherwise engage the whole time of man and prevent the acquisition of knowledge.

All great reasoners on moral philosophy and historians have agreed that civilization is a sequence of—first, an accumulation and surplus of wealth—secondly, an accumulation of leisure, or time, in which man is freed from drudgery, which is a consequence of the first condition. Thirdly, the accumulation of knowledge, as a second sequence, follows the surplus of time, or leisure, in which it can be acquired.

Granting the truth of this proposition, when we come to analyze knowledge and to divide it into the several branches, and estimate the influence of each in promoting its further dissemination, and as affecting the material interests of civilized people, the engineering arts stand out boldly as what we will term the great "motive power" of modern civilization; the very foremost, indeed, of the great causes that influence it; the power that gives man control over nature and brings to his aid those forces and machines without which he is powerless. It is therefore quite natural that we should associate our ideas of civilization first of all with what a people may know of useful art, and from this, as a standard, gauge the degree of their civilization.

That modern engineering and the mechanic arts are but the appli-

cation of the laws of physical science is true, but that in time past they have been in a large degree developed independent of the aid of science is equally true. The rule has been for the engineer or mechanic to demonstrate results, and then, from those results, by a negative course, trace back the antecedents until the laws which governed them were discovered. This matter, which will be noticed at more length in another place, is mentioned here to show that engineering progress has been in the past a branch of knowledge that has pursued its way in a bold and independent course, manufacturing its own resources as it went along.

As the metaphysician has always looked with a spirit of emulation and rivalry upon the scientific man, he has in turn estimated the application of science in engineering as an inferior and secondary matter, not realizing that they were both engaged in different branches of the same pursuit, having such a correlation, and such an intimate connection, that as time and knowledge progressed they assimilate more and more until we now can realize that in the future there may be no line of distinction, and all will become as successive links in the great chain of human knowledge. The applied sciences will, like the tools of the workshop, be brought to bear upon every operation involving force, movement, or composition of material, and even the influence of scientific and industrial pursuits on civilization will become a matter of standard rules and laws.

Engineering progress is divided into two branches, or rather, is capable of such subdivision, for the purposes of inquiring into its results and the causes that influence it. It consists first in the conception of new plans, new applications, or new results, and in the mechanical agents that carry such conceptions into practical effect. The distinction is in some cases so clear that scientific men sometimes from their deductions arrive at important mechanical discoveries without any ability to create agents for their application. This distinction is, perhaps, as marked as any that can exist between any two branches of what can be classed as belonging to the same science, or as we may, for the want of a more proper term, say, the same "art."

To better illustrate the meaning intended we will take for

example the art of printing. It is the result of two elements—the original conceptions of Faust and Gutenberg and the mechanical means of carrying out those conceptions so as to distribute the result among the people. It is quite unfair to award the whole praise, or even the greater share of it, to the conception or discovery of Faust because it preceded those greater achievements which rendered it available. Without the ingenious machinery used in printing, its cost would place it beyond the reach of the masses; or, if cheaply produced, it could not be distributed without our modern means of transportation. Viewed in the abstract it is a means of transmitting thoughts and ideas; a vast system, consisting rather of the achievements of civil and mechanical engineering than the remote discovery of a Faust.

So it is with all those great agencies that have influenced the progress of civilization and the acquisition of knowledge; so far, at least, as physical causes are concerned.

If to this we add the other fact that such physical agencies have been the principal and great cause of human progress, we can begin to estimate and realize the relation that the industrial arts bear to civilization. It is not, however, within the province of this work to pursue this subject, which is only alluded to for the purpose of ascribing that proper dignity to engineering industry which is its natural right, and which its history and influence has in the past so nobly maintained.

England was the first country to accord that dignity to engineering which placed it upon a true basis; and was, we may also say, the first to adopt the direct means of its development. The line of social distinction is there drawn between the man who thinks and the man who barters, and for the result we have only to point to the effects of the policy in her vast wealth and commerce—that dominion of power created and sustained upon the supremacy of her engineering resources. With but a limited share of those natural elements that contribute to the accumulation of wealth and power, she has led the commerce, the literature, and the civilization of the world; and if we were to follow back from the result to search for causes we

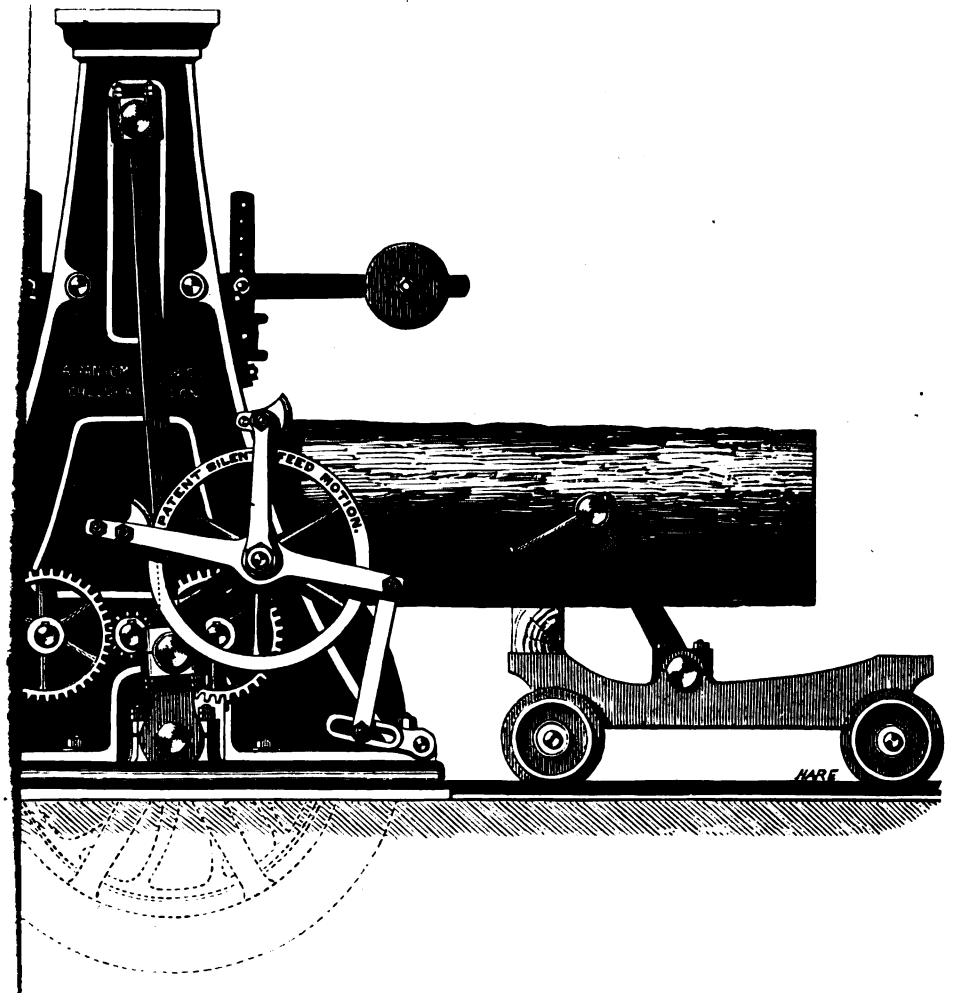
should come to physical science, not directly, but as antecedent to the immediate one of civil and mechanical engineering.

As the subject of this treatise has to do only with what we will term mechanical, or dynamical, engineering matters, it will be proper to point out the distinctions on which the term is based; or rather the sense in which it is here used, for it is not assumed to fix a further standard.

The sense, then, in which it will be used is as relating to the construction of machines and works that involve motion as distinguished from structures that are in a state of rest, and without motion.

The term "machinery" means and conveys the idea of agents for employing and transmitting motion and force; and the special knowledge required to understand the various conditions of their operation makes the distinction between what is termed mechanical and civil engineering. This knowledge of the conditions of operating is one that of all others is most independent of physical science; for although everything in the operation of machines is governed by laws as fixed and constant as those that furnish proportions for their several parts, their operation is much more obscure than their construction, and cannot be so readily determined from theoretical influences.

That this will always be the case does not follow, but that it is so now cannot be disputed, especially in machines directed to wood cutting, where the high speed of the cutters gives rise to various conditions which are exceptional, not to say anomalous. To assist in inquiring into the operation of such machines, and to consider its bearing upon their construction, will be the object of what follows, and if it adds in any degree to the progress of engineering in this branch the writer's object will be fully attained.



Weight—From 2 to 4½ tons.

Scale—$\frac{1}{24}$th, ½ inch = 1 foot.

INVENTION AS AN ELEMENT IN THE IMPROVEMENT OF MACHINES.

That the development and improvement in the useful arts, especially in mechanics, must depend in a large measure upon what is known as "invention," is obvious. So long as our knowledge of scientific laws is not sufficient to force out results by "mathematical demonstration," we must depend in some degree upon "discovery" or a "finding out," as if by chance, many things of importance. We must in the future, as in the past, look to invention as one of the agents in developing wood-cutting machines; it will therefore be correct to inquire how invention can best be directed to the object sought, and to some of the rules which can be applied so as to reach results with the least expenditure of thought, time, and experiment.

Invention in its popular acceptation means discovery, a finding out of that which was not before known, not by logical deduction, nor by following out a connected chain of reasoning from fixed premises, but a kind of intuitive perception of the thing wanted, in other words, a sort of revelation to the mind governed by chance. It is of course expected that these discoveries when made will, of necessity, be found to agree with the established laws of science, and yet it is the exception and not the rule for an inventor to trace out his inventions by means of these laws. It is the difference between hunting for the lost end of a thread, by groping about without anything to guide, or by going to the other end to follow the thread itself to the missing end.

The popular acception of invention, or rather the popular idea of invention, is in many respects incorrect, and has done almost as much of late years to hinder progress as to promote it. We say of late years, for since the discovery or demonstration of the mechanical equivalent of heat, the laws of forces, and other scientific data affecting mechanics, this chance invention has declined by the very force of circumstances.

Previous to this it cannot be denied that it gave to the world by facts and demonstration, a great share of the rules and data which were afterwards confirmed by the laws of science.

That inventions are thus divided into two classes, or rather that they can be so divided by proper distinctions will not be questioned. And it is an interesting study to follow back the history of the mechanic arts to a time when, like chemistry (or alchemy), they were surrounded by a veil of superstition, for there has been a time when it was equally the province of the tailor or cobbler, with the engineer or machinist, to invent machines, when premiums were offered for "perpetual" or "self-acting" machines, when devices for generating and augmenting power were sought for, and when mechanical improvements were looked for in the field of chance or discovery alone. It is difficult to account for, or even to realize now, how such great advances were made, in the absence of nearly all the data which we have at present to aid invention.

To more fully illustrate this distinction between what may be termed legitimate and illegitimate invention, we will imagine a case as follows. First suppose that a want or an existing fault has been discovered, and that fault to be the tendency of railway trains to overturn in rounding curves.

We will then suppose two persons representing the two schools of invention to set about its correction. One of them the schemer of fifty or even twenty-five years ago, and the other the educated engineer of the present time. They both have the same object in view, the same end to attain, and the difference will be the plan set about to reach it. The first commences by racking his brains for mechanical expedients to hold the carriage down: he thinks of gib hooks under the rails, a shifting load that shall be transferred from side to side to meet this tendency to overturn, or perhaps a permanent load too great to be overset; he thinks of widening the wheel base, of lowering the carried weight to get it between the rails, and many other mechanical expedients, until finally some one is selected as most feasible and *tried*, is found wanting, is modified, and again tried, resulting in a second failure; another expedient is then adopted and

tried with a similar result, and so on until, at the end, a little practical information is gained from all this waste of time and money, while the experiments themselves have done more to weaken confidence in engineering than the information gained is worth.

We will now suppose the other view of the case, representing what will be termed legitimate invention.

The engineer discovers at once, as the cause of this tendency to overturn, a force or property of motion which is familiar to physics, and from premises that he knows to be correct, he estimates the amount and direction of this force in pounds, based of course upon the available conditions of the case. This force he finds acting in a horizontal plane, bearing certain definite relations to the weight of train, width of wheel base, position of the load, the centre of gravity, &c. Having ascertained the several conditions with certainty, he next sets about a remedy. Still following the laws that science has laid down, he reasons that the direction of this force cannot be changed, neither can it be destroyed, hence to be overcome it must be met and neutralized by an opposing force acting in a reverse direction; he casts about for such a force to oppose, but cannot find it; he, however, discovers one acting at *right angles*, that of gravity, which can be employed; it is found already acting, but not in a sufficient degree; he raises the outside rail of the permanent way, and shifts the position of the centre of gravity until it balances the tangential force that tends to overturn the train, and the whole is accomplished.

Nothing has been supposed, nothing has been risked, nothing has been tried, and nothing has been lost. The whole has been demonstrated upon paper, with a perfect confidence from the beginning that although the ultimate object might not be fully attained, yet that all could be done that, in the nature of things, was possible.

This picture is not overdrawn, but has its parallel in every branch of mechanics, and more especially in wood machines, a less perfected art than railway engineering. To illustrate the workings of the two systems as applied to wood cutting, let us suppose that the "buffer beam" or "end sill" of a railway carriage is to be worked out

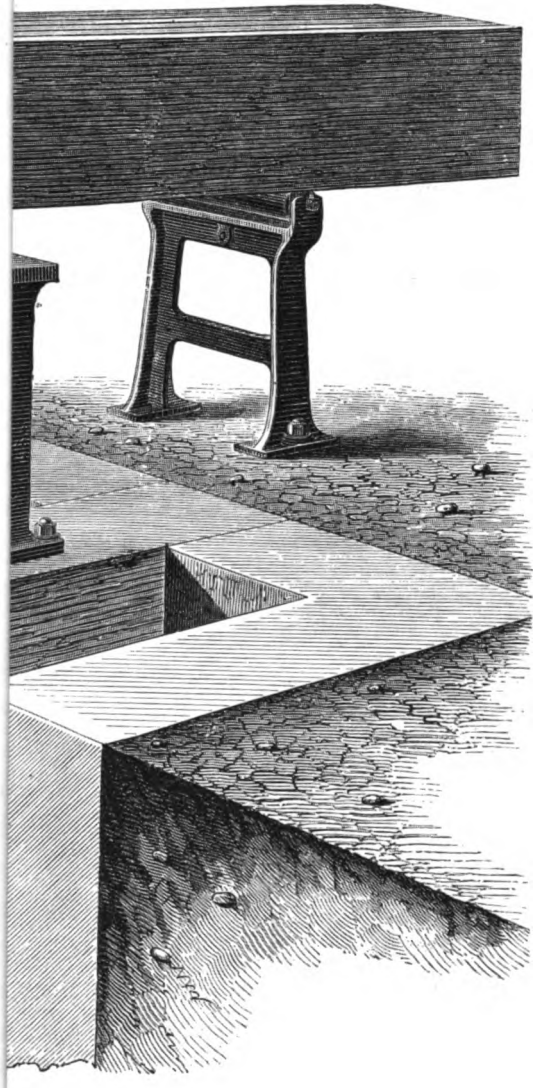
by power instead of by hand tools, and that the want of such appliances has been realized. The one inventor will begin by imagining a cutter-head or spindle to make such a mortise or such a gain, a planing tool to dress the surface at various parts, will scheme the thing in his mind until some kind of an organized machine is conceived of. It is built for experiment, a cutter-head is improved, a spindle is changed, adjustments added, improvements go on, machine after machine is made, each doing its work, and each better than the last, until by practical experiment and demonstration the machine has assumed something like a standard construction, through what may be termed chance invention.

We will now assume that an engineer educated in modern practice, and acquainted with the action of cutters, is called upon to design machinery for the same purpose: his course would be as follows. He begins not with a confused idea of cutters, shafts, stops, and belts, but by first considering the movements involved; he applies the *laws* of relative motion in machine construction, and finds beyond any question, that for longitudinal adjustment, the wood or piece should be adjusted, a condition determined by cost, convenience of operation, &c. He next finds that to finish the piece, there must be also transverse movement; by a second application of the same laws and conditions of construction he finds it cheaper and better to move and adjust the cutting tools than the beam itself, just the reverse of the conditions in the case of longitudinal adjustment.

Next he considers the cutters, whether to have them operate parallel to, or transverse to the fibre of the wood. Certain parts are to be painted, other parts are to form joints. Cutting longitudinally, or with the fibre, gives a smoother surface, but requires more power and is more apt to spring the timber. Certain other parts must be cut transversely, on account of shoulders, or buttings.

Experience has already furnished him information about the forms of cutters, and the inventor is at no loss to determine their proper form for this case, keeping all the time within some fixed data for all that he does.

Next we will suppose him to come to the question of adjustment,



vertical, transverse, and longitudinal, of the cutters, carriages, spindles, &c.

A list of the timbers to be worked will of course give this, supposing the position of cutters to be constant, but some of these are subject to wear, and to reduction of diameter or length: the adjustment to meet this must be either added to the spindle or carriage; the tension and position of belting and shafts is then considered, also means of cramping the stuff in such manner as to resist the action of the cutters without springing it, whether its length is uniform, if so whether it can best be held by end compression instead of side clamps.

Now by this form of reasoning and by deductions made from rules, laws, and data, a machine is generated that is in the main a perfect one, and it will remain substantially the same as long as the art lasts, or until a subversion in whole of the principles that now govern wood-cutting machines.

This is a legitimate invention, or rather deduction, that has nothing to do with chance, or even with discovery.

We trust that this distinction between chance and logical invention will not only be discussed, but generally understood, and that a new class of inventors and improvers will take the field, especially in the improvement of wood-cutting machines.

It may be added to what has been already said, that to chance inventors belong the whole category of perpetual motions, machines or devices to augment power, with other foolish things that annually consume thousands of pounds in time and money, and, so far as useful invention is concerned, leave the art in a worse condition than when they began. It is therefore the duty and should be the aim of every engineer to establish constants, and learn the laws that govern the action of machines, and to hunt after principles rather than results; where data is wanting supply it, so far as possible, and build on law and system instead of chance, and what is termed ingenuity.

Granting the foregoing views in regard to invention, the question will arise as to how far the present knowledge of the laws of force, motion, and construction in general will supply the data from which to build a machine. To which it may be answered that an inability

to construct machines that shall be measurably perfect, can only be attributed to a want of understanding such laws, and that so far as they can be applied, or are understood, they furnish the true and most reliable rule to follow in designing machines.

In civil engineering there is no one will dispute that it has become almost purely a mathematical science, the strength and disposition of material in a state of rest has assumed certain standards that the world recognizes as substantially determined; if so in civil engineering, why not in dynamical engineering? There is certainly nothing in the laws of forces and motion that precludes the possibility, and it is only that our knowledge is not yet sufficient to fix such standards; we are, however, fast approaching it, a proposition that it requires only an observation of the facts to prove.

THE PAST AND FUTURE OF MACHINE MAKING.

Speculation as to what is yet to be discovered in machine making furnishes an interesting theme, not only for humour or satire, but has a legitimate place as affecting the present.

It is a common expression to hear that if twenty years past has produced such wonderful changes and improvements, what can we expect in twenty years to come? Such speculation is based upon the proposition that improvements in machines bear a constant ratio to the amount of scientific knowledge acquired, and presupposes unlimited functions for machines. However true such a rule may be when applied to the past, we must not apply it to the future; in fact the very reverse of the proposition is more likely to be true, and as we accumulate scientific data and experience the improvement of machines will diminish. In other words, when there is acquired a full knowledge of the functions of a machine, and the laws that govern its operation and its construction, so as to best meet these conditions, such a machine is in a sense finished, and cannot again be changed in any great degree so long as its objects remain the same.

To give facts in support of this proposition we can refer to machines for cutting metal, engineering tools, such as drilling, planing, slotting, and shaping machines, lathes, wheel-cutting machines, &c., acting as a rule only in straight lines or by rotation, with a slow movement, and for this reason admitting of endless modification in design and arrangement, yet we find them now and for twenty years past built substantially in the same manner. Tools of this class, exhibited in the first Exhibition in London in 1851, were very much the same in arrangement, and quite the same in their functions as those shown in Paris in 1867, or as they are at present made. The plans of Whitworth for machines for planing, shaping, slotting, and turning metal have not been materially changed in that length of time, and it is reasonable to suppose they will not be much changed in the future, which only argues that in their original arrangement, the inventor considered laws and not chance in his designs. Steam as a motive agent cost no more, or at least but little more, twenty-five years ago than it does now, and the steam-engine, considered as a machine, and aside from steam-generating apparatus, stands just about where it did eighty years ago.

There is now in use in the City of London a vertical beam-engine built by Boulton and Watt in 1785 that performs its regular duties with an effect that is not much different from that of a modern-built engine that operates in conjunction with it.

Dimensions for parts, and even the arrangement and general design of stationary and locomotive engines are becoming fixed and generally acknowledged as standards, so that it is unreasonable to look for such a revolution and change in general machine making in the future as has been experienced in the past. It is perhaps also safe to assume that invention, at least in its popular acceptation, will not increase but will diminish, or rather machine development will not be regarded in the light of invention. In future, machine designing will, however, be done more by engineers and less by experimenters, at least in such arts as are popularly understood and have been the subject of scientific investigation.

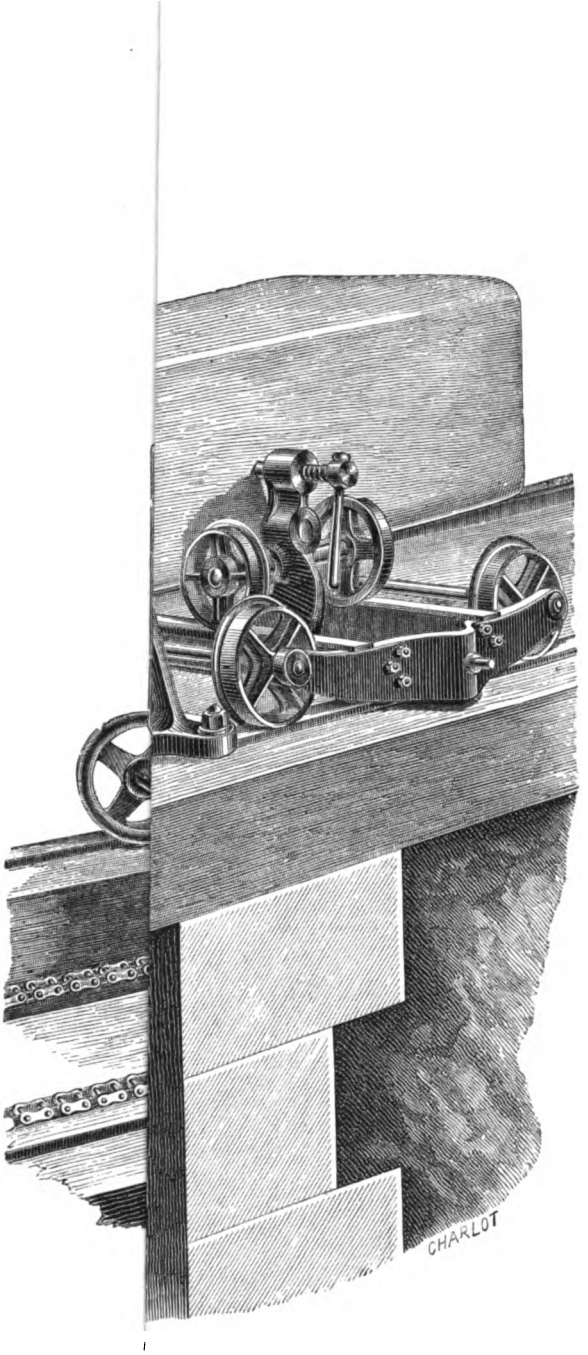
That these propositions are anomalous the writer is fully aware,

and he disclaims any intention of including wood machines with those for cutting metal, or machines for any well-known branch of industrial manufacture; they are behind in this great race for standard construction, through neglect, or for reasons that will be noticed farther on.

ON WOOD-CUTTING MACHINES IN GENERAL.

The foregoing views we would not wish construed as arguing the possibility of a common standard for wood machines, in the same sense that the term can be applied to those for other purposes. While the general arrangement, and even all the needed modifications, can in some degree become what we will term standard, there is such a variation of conditions that it will require more skill and a longer time to bring it about.

Metal-cutting machinery has the same material to deal with in all parts of the world, or at least with no variation that need be taken into account in their construction. Iron is the same in texture and resistance to tools; its grain or lamination has nothing to do with the direction in which it is cut nor with the action of the tools. The same rule of uniformity applies to nearly all kinds of material that is manufactured by machines, except wood. Wool, cotton, and flax are about the same everywhere. Hydraulic and steam machinery operate under uniform conditions at all times and in all places. Wood machines, however, require special adaptation in relation to the material to be wrought, which is not uniform, nor even analogous, when we consider the extremes between the hardest and the softest timber, and the very different nature of the operation of cutting and shaping it. Between the soft fir-timber of northern climates and the hard woods of the south there is almost the difference that there is between rosewood and cast iron. In some of the very hardest varieties, such as lignum vitæ, rosewood, cocoa, box, and ebony, where proper tools for working them are a kind of link between wood and



endless chain.

metal-cutting machines, cutters and other details must be made to suit. The operations too in working wood are more varied than those of almost any other branch of manufacture. Some of the leading manufacturers make as many as eighty different machines and modifications, which is the more surprising when we consider that they are all cutting machines, that is, working with sharp edges, and not to be contrasted with those for metal work, which include punching, forging, and grinding machines.

To present the difficulties that will have to be surmounted, or rather to estimate the comparatively greater work to do, in establishing fixed rules and constants for the construction and arrangement of wood machines, is by no means intended as an argument to show its impossibility. To overcome difficulties we must first understand them, after which the task is comparatively easy. To trace out the necessity for this special modification is directly in the way of finding rules to govern it.

Besides the endless modification necessary, another thing that will no doubt, for a time, hinder wood machinery from assuming a standard form of construction, is the want of information that exists relative to high speeds for shafts, cutters, &c., which will undoubtedly for a long time remain a matter of opinion instead of a matter of fixed law. No other class of machinery compares with wood machines as to speed. There is, it is true, in many kinds of manufacturing, and in various machines, an occasional spindle that is driven at a high velocity, but what is exceptional in other machines is the constant rule in all rotative wood machines. Balancing, the nature and dimension of bearings, centrifugal strain, and lubrication, are all questions that must reach a settled standard before there can be any uniform plan of construction looked for. Belonging to, or having its greatest importance in, wood machines, is the subject of high-speed bearings. Although one of the utmost importance, it has not been the subject of experiment, or even discussion, so far as yet made public. In fact the information relating to the bearings of ordinary shafts is of the most meagre character considering the importance of the subject, and engineers adhere to opinions that are widely different,

both as to material and dimensions for bearings. A further difficulty to contend with in attaining standards in wood-machine manufacture at the present time is that they require to be made cheap—at the least cost compatible with successful performance. This is necessary for the valid, though anomalous, reason that the art is a very imperfect one, and the life of a machine, or the time it will continue in use until supplemented by improvements, is a question that has much to do with the amount of money invested in it. This matter, in an indirect way, retards improvement, both as to the character of the fitting and in design; the first to avoid cost, and the second in preventing that care and study which would otherwise be given to their plans. In England and on the Continent an argument for cheap construction based on such a proposition would no doubt be out of place, for reasons that will appear when we come to notice the requirements of the different countries, but in America this very thing, inconsistent as it may seem, is one of the great, if not the greatest, reason that wood machines are so cheaply made and wanting the greater durability that characterizes those of European manufacture.

In proof of this it can be safely asserted as a fact that there are throughout American factories but few wood machines that have been running for ten years, and if any such exist there is a good and sufficient reason for abandoning them. The life of most machines used in joinery is not on an average more than six years, under any special modification. So general is this rule that in the sale of patents for wood-cutting machines their value is based upon a monopoly that will not exceed that time. For this reason it is easy to see that manufacturers who use such machines do not care to make large investments in machinery that will in so short a time be out of use.

The American market for wood machines will, however, be more fully considered in a subsequent place. Having briefly alluded to some of the difficulties that stand in the way of reaching standard rules, in the construction of wood-cutting machines, and why it would under the same conditions require a longer time than for those used in cutting metal, we now come to the main reason why the same advance has not thus far been made; it is that their designing

and manufacture have not been recognized as a regular branch of engineering. They have been practically ignored, while many other things of much less importance have received greater attention. This assertion, which is made in the preface, is repeated without any fear of successful contradiction. Indeed, a single fact will suffice to prove it.

If you go into the British Patent Office to examine the records relating to patent inventions, in almost any other branch of engineering, you will find prefaced a separate and classified volume of the subject-matter of all patents pertaining to the subject, but of wood-cutting machines you will find none; if you go to the library in search of books that treat of such machines, you will find none; if you turn through the Encyclopædias and Dictionaries of the Arts, you may or may not find mention of a sawing or a planing machine. Read over the Proceedings of Engineering Associations, and there is nothing, or next to nothing, about wood machines; and when anything does appear, it is not by any means in keeping with the papers that are read or addresses made on other subjects generally in the way of amateur observations, or a plain description of what has been done, a mere recital of facts, which suggests nothing new and demonstrates no errors in existing practice.

The paper of Guilford L. Molesworth, C.E., on "the conversion of Wood by Machinery," read before the Institute of Civil Engineers, London, in 1857, was the most extensive thing of the kind that had to that time, or has since, appeared in the English language. In fact, this paper, the patents of Sir Samuel Bentham, the paper of Prof. Willis already alluded to, Worsam on Mechanical Saws, and the author's contributions to the Journal of the Franklin Institute, constitute our total stock of technical literature relating to wood machinery.

Granting these facts as proving the ostracism of this branch of engineering, it will be proper to inquire after the reasons that have led to its neglect.

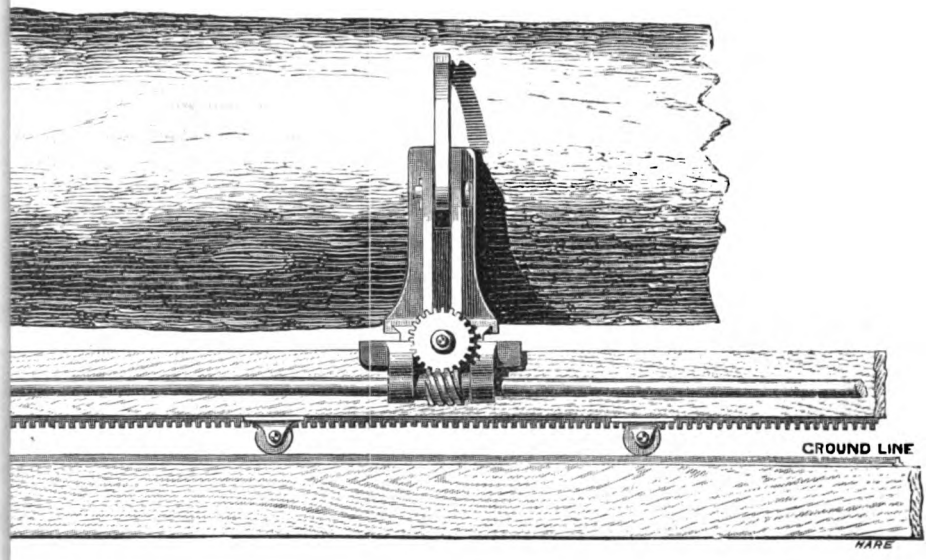
They certainly are not found in a limited extent of the interest, in England and America at least, for it is neither small nor unimportant. It is to be regretted that there are no statistics at hand to

show the amount of wood machinery that is now made by the several engineering firms who make this kind of machinery a speciality, but it could no doubt with safety be set down for the last year in England and America at a value of not less than 500,000*l.* sterling; besides, it cannot be reckoned in its importance on the same basis as many other branches of manufacture, that of monetary value; it has a deeper significance in connection with the material advancement and welfare of the country. All the machinery of this kind made in America, and a large portion of that built in England, is for home use, to assist directly in developing the resources of the country, in building houses, ships, furniture, and thousands of articles of convenience and necessity that have quite a different relation to civilization, from that of brewing and distilling spirituous and malt liquors. In fact there is no branch of manufacture that has a more intimate connection with the interest of all than wood conversion. However humble, everyone must have houses and furniture, waggons and ploughs. A people have lived, as in North America, without metals, or at least without more than cutting edges for wood and for ploughing the soil; but to live without wood and the ends it subserves would be out of the question.

Another reason for a slower development of wood machines is that those who build them do not operate them. Machines being made, at least in modern times, of metal exclusively, it is quite a different matter to build the kind of machines that are used in constructing others, or to build them for a purpose that bears but little analogy to the operations of a machine shop.

With machine tools, and all machines to work metal, the men who build them are familiar with their functions; everyone connected with a manufactory is an operator of the machines built, but in wood-work machines it is quite the reverse. The men who work on them are as a rule quite ignorant of the purposes or functions of the machines.

Another distinction from other branches of engineering is found in the segregated character of the work, the machines are small and to be considered separately.



d blocks. *Weight*—From 3 to 4½ tons.

d Co., **Engineers, London.**

A steamship, a pumping engine, or even a locomotive engine, is a great work compared to any machine that is built for working wood. The attention of engineers and the public is directed to such things in proportion to their individual magnitude, instead of their aggregate importance, a fact that has done much to retard the progress of minor branches of manufacture, and contributes most to those of less importance, but of more notoriety. Wood-working machines were at first made as a rule by carpenters, and not by engineers nor machinists; this was especially the case in the United States twenty years since, when nearly all makers of wood machines were themselves wood workmen. Machinists could not of course build machines, the functions of which they did not understand; geometrical drawings to embody the ideas of the wood workmen were in this, as in other branches of industry, almost unknown. Hence the carpenter, cabinet-maker, and ship-builder set about to construct machines that would perform by power what he had before done by hand; iron was to him a new material; he had not in his mind constants, or rules for proportions, like an engineer or machinist, but blindly supplied a shaft here, a pulley there, with bolts and framing to support them, very much as he would have made a house. The movement and application of the cutting edge was the prime object, everything else unimportant. This same fact accounts fully for the peculiar designs which we see in the framing of American wood-working machines. The carpenter carried out his architectural ideas in their arrangement, the metal was disposed in scrolls and network, and all conceivable forms except those that the strains would indicate, figures of vines and shrubbery, "pomegranates and lily-work" were raised in relief, the whole was painted in gorgeous hues, and as if to cap the climax, the rough iron surfaces were generally finished off with a coat of transparent varnish.

This system of framing and painting on wood machines is yet common throughout the country, except in such establishments as have attempted to introduce the practice of modern engineering, but will no doubt fast disappear when it finally becomes, as it must be, condemned by popular taste as well as common sense.

It may be added that if the wood-working ideas of the first builders of wood machines led them to extravagant and uncouth designs and want of true proportion in the parts of their machines, their operation was not open to the same criticism. Nowhere in the world have the machines for making doors, sash, and joiner work generally equalled those made by these carpenter builders. Their first cost was trifling, yet the amount and character of the work produced was a maximum. This will, however, be reverted to elsewhere. The object of noticing this history of the art here is to show another of the many reasons why we find machines for wood work lacking in design, when contrasted with those for other uses.

Wood work, unlike most other kinds of industry, is not carried on at centres—it is isolated, spread over the whole country. This too has had its effect in preventing the development of machines; for any business, no matter what, attains a perfection only where it is largely carried on.

It is an aggregation of information in one place where one person can learn all that the many know. Wood conversion in this regard compares with agriculture, it is a general necessity, and the amount of wood work done is in a constant ratio to the population of most civilized countries. Concentrated at one point, like machine-tool making at Manchester or Philadelphia, or ship-building on the Clyde, it would soon reach the same perfection that has been achieved in these arts.

In America a village of two thousand or more inhabitants, with the surrounding country, is said to be large enough to support a planing mill; which then means, a regular wood-working manufactory, equipped with saws, planers, lathes, tools for mortising and boring, in fact all operations in wood work. So general is the want of such work in America, that there is not perhaps in the whole country a village of the size mentioned without its planing mill, and perhaps a half-dozen other establishments making specialities for the general market, or ploughs, waggons, furniture, &c., for local trade. Very little hand work is done; in the language of the country "it don't pay." A man costs from fifteen to twenty dollars a week, but a

"man power" in a steam-engine don't cost as many shillings, hence the steam is the cheapest—it don't strike, is always at its post, and is easier controlled. The intelligence it lacks must be supplied in the machines. This is the American idea of wood work in general. Prices are uniform all through the country, and hand work is out of the question. Wood-cutting machines are made in all the cities in America, besides numerous shops scattered over the country, that make more or less, but as said, there is no special centre for this kind of work, either in America, or in England, where the same rule holds; wood machines are made in various parts of the kingdom.

A fault common among builders of wood machines is the jealousy that exists, and the inclination to keep their shops closed, or their plans secret, an error that prevails with all kinds of manufacture when undergoing change and improvement. It, however, disappears as an art becomes more perfect, and will no doubt be so in this case. Considered in its effect, this "lock-up" plan is a foolish one except as a guard against annoyance; the machines made must embody the plans of the maker, and must go to an open market. There is nothing to hide except shop manipulation, which, so far as the author has observed, is quite behind that of our machine-tool makers, and presents nothing worthy of imitating.

THE RELATIONS BETWEEN HAND-POWER OPERATIONS IN WOOD WORK, AND THE GENERAL PRINCIPLES THAT GOVERN WOOD CUTTING.

Although the relations between hand and power operations as to cutting, feeding the material, adjustments, &c., will be continuously alluded to farther on in the work, it is thought that a kind of general summary would, at the beginning or previous to entering upon mechanical details, be desirable.

As repetition of what will be said in its application to particular machines will be unavoidable, it is trusted that the difficulty of framing a systematic plan for a treatise on a new subject, based

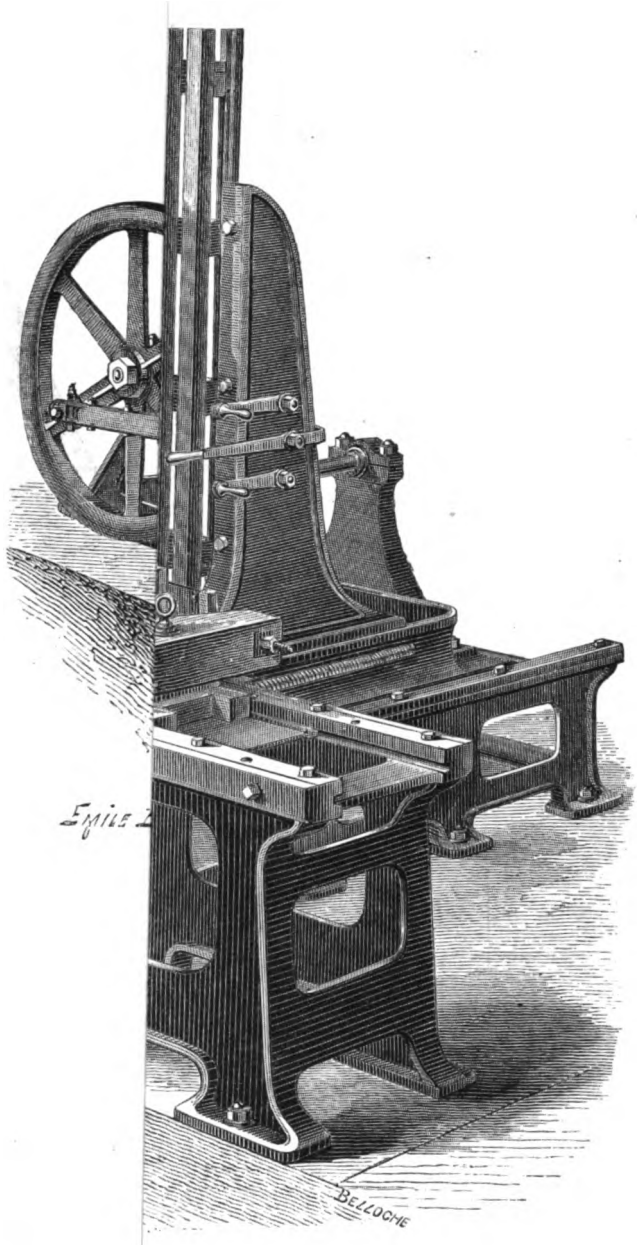
almost entirely upon personal experience and observation, with the absence of the usual references and data, will be a sufficient excuse for the imperfect arrangement, a matter that would be easy to correct in a subsequent work, or upon a revisal of this, which is at the present time impossible.

To assume that the operations of machines for cutting and shaping material are not in their working governed by certain fixed principles would be an assumption as unwarrantable as it would fifty years ago have been to say that there were no constants to be fixed for the strength of material, for the force of heat, or any of the now familiar rules that guide the engineer in his plans.

Such laws or principles will certainly in time be understood, but our acquaintance with them will not be the result of discovery or invention, but from carefully-collected facts, the result of observation and experiment by those who build and operate machines. When these facts are sufficiently full to form a tangible basis for theoretical deduction, then the progress will be rapid, and physical science will supplant opinion and experiment; machines will assume a regular and standard form of construction.

Hand performance is at present what we may term the basis for estimating the performance of machines; nearly all kinds of manipulation performed by power has first been done by hand, and the usual estimate that presents itself first to the mind is the contrast with hand labour. As the work of a horse became the unit or standard of power for the steam-engine and the measure of natural forces, so has the hand performance of a workman become the standard of performance for wood machines, not as a measure precisely, but a kind of basis from which we derive our opinions of their results.

Wood, as a material, unlike metal, is not being continually applied to new uses; neither is there being made discoveries that affect its composition. Wood is a natural material, with the composition of which we have nothing to do, and the whole subject of its manufacture relates only to cutting and shaping it. Hence hand operations have in time past comprehended about all that we can ever expect to perform with machines, and the machines, instead of intro-



natic intermittent feed.

ducing new processes and new uses, merely supplant hand manipulation in the several ways which we will now proceed to notice.

The following propositions are laid down as premises, which will each in their turn be separately considered in the course of the article.

First. The object of machines in wood work, as contrasted with hand labour, is to augment force, to guide cutters in true lines, and secure a greater rapidity of movement.

Second. The direct effect of machines is as the amount or length of cutting edge that can act in a given time.

Third. This effect or result is limited by the nature of the operations, and by the accessibility of the surfaces of the material to be acted upon.

Fourth. This limit of application governs the relation of machine to hand labour, and whenever hand manipulation approaches what can be done with machines, they should not be used, and cannot with profit be applied.

Fifth. The performance of any machine in relation to hand labour can by these rules be predicated, and its labour-saving effect be determined.

In the first proposition, which is divided into three heads, we commence with the question of force. Taking the carpenter's plane as one of the most perfect of implements known, that has for centuries and in all countries remained about the same, we find that the amount of work done with it in a given time is dependent mainly upon the strength of the man who uses it.

The cutter, instead of being 2 or 3 inches wide, could, if the power was sufficient, be as wide as the lumber to be planed, and the length of cutting edge that is acting is limited only by the power that propels it.

We find too that the motion is reciprocating and does not exceed, say, 100 feet a minute during the cutting action. We find also that the cutting is gauged from the surface of the wood that is being acted upon. The tendency of the tools is to produce a plane, yet it is a matter determined by the eye, and not by positive means.

These being the conditions of hand labour in this particular operation of planing, let us, according to the propositions given, proceed to determine how far machines will facilitate it, save labour, or save cost, all of which amount to the same thing.

Force can be used in any degree: force is the first and main element wanting; by increase of force we increase the cutting edge, and the result is greater accordingly.

Next, speed of movement: this can also be applied in an unlimited degree; instead of 40 feet a minute the cutting edges can move 10,000 feet a minute; cutting during one-tenth of the revolution gives 1000 feet of cutting movement.

Then, in guiding the cutters we find that this is easily done. The reciprocating motion is incompatible with high speed, and is changed to rotary motion. The cutters revolving about an axis are of course guided in a most positive manner.

To go on still farther, we find that in this operation of surface planing, the extent of the operation is not limited by any special conditions; we can use four or more feet of cutting edge, and the extent of surface is, too, in a sense not limited; 100 superficial feet of surface, if desired, can be presented in each minute to the action of the cutters.

Planing, then, we find to be as a hand operation a slow one, also one that admits of a complete and economical application of machines to effect the same purpose.

It was assumed in the two cases that the length of the cutting edges could be increased from 2 or 3 to 24 inches long, say eight times, and that these edges could be moved during their cutting action at a speed equal to 1000 feet a minute, as contrasted to 100 with the hand plane.

To make a comparison, we must first multiply the hand labour by eight for the increase of edge, and this result by ten as the gain in movement; then double the result on account of the continuous action of the machine, and it gives a result as one to one hundred and sixty.

The premises are of course in a large degree hypothetical, but to go to the actual facts in regard to planing by hand and planing by

power, it is for surfacing boards about as one hundred to one in clear soft lumber, or as two hundred to one in hard rough lumber; in other words, it is about as the first deductions would show, reasoning from the premises assumed.

We will next take sawing wood for an example. In this, as a hand operation, we find, as in planing, that the amount of work done is limited by the want of physical force in the operator; he can easily apply all his strength and motion without tasking his skill, which is scarcely called into use. The amount of cutting edge cannot, as in planing, be increased, but must remain as the kerf and thickness of the saw-plate. So far as guiding the action of the edges, very little is gained by using machinery, as the edges are effectually guided by hand. This then limits the salient points of the operation to that of speed, and as speed is the only one to get the best result, it must be as great as possible in any machine intended to supplant hand labour. In sawing by hand we will assume the cutting movement to be at the rate of 100 feet a minute; dividing for the return stroke and intermittent motion, it is reduced to 50 feet at most if considered as continuous action.

In power-sawing with circular saws, the cutting movement is, say, 10,000 feet a minute.

The saw is cutting continually, and not at intervals as in the planing machine, hence the true ratio of movement is as two hundred to one, and if the facts of actual practice are examined, the result will not be found much different from the estimate.

This gain by machines is based upon speed alone; but the high speed at which saws can be run compensates in a measure for what might have been gained by an increase of edge at the same time.

These examples are given to illustrate the manner in which the writer would propose to analyze the functions of machines, and predicate from previous deductions what their ultimate labour-saving effect would be; so far as the writer has been able to apply them in actual practice, and so far as the past history of cutting-machinery will show, they are substantially correct.

In the first proposition, involving power, motion, and guidance

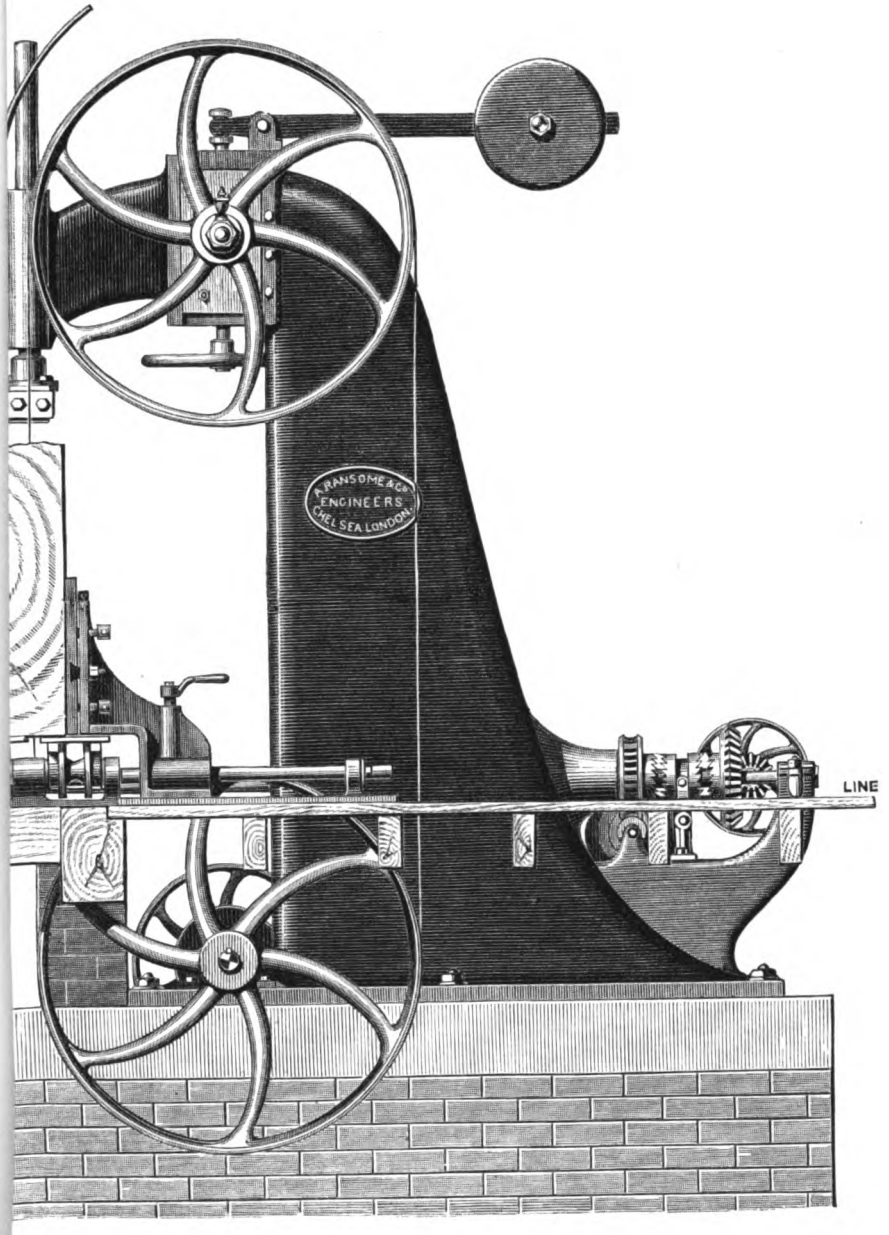
of tools, we have only to apply it to any of the familiar operations in wood work to ascertain its general truth. The examples of planing and sawing show one extreme; cases in which the effect of machines, when contrasted with hand labour, represents a maximum saving.

In dovetailing, carving, or boring holes, we have the other extreme; either a limit of cutting edge, a limit of surface to be acted upon, or conditions that do not admit of increase in power and speed. In carving, the cutting edge is very limited; the movement is, from the small diameter of the tools, also limited. The prime object of the machine is guidance of the tools by the duplicate. Such machines, therefore, cannot be said to avail themselves of the two great advantages of augmented power or force and higher motion, but are limited to directing the tools. As to the history of carving machines thus far, leaving out special cases and taking the result generally, it has been an even race against hand labour, to say the best, and gives no great promise of a gain in the future. In this assumption we are guided by the only fact that is entirely reliable in the matter, which is, that carving in both England and America, as well as on the Continent, is mainly done by hand. In the case of dovetailing the same rules apply, except in a less degree, and the result is the same when we follow the history of the machines.

Sir Samuel Bentham, in 1793, describes the conical cutters for dovetailing, which form the ruling principle of the latest machines. Eighty years of battle with hand labour has gained no advantage, because it has been waged in violation of those inexorable mechanical laws, that will reappear and assert themselves, no matter what fair promises a machine may make for a time.

The second proposition relates to the amount of edge, or the length of edge, that can be brought to act at one time.

Considered in the abstract, this is the same thing as speed, or the amount of edge acting in a given time; but applied to practice, and considered in reference to actual cutting, it becomes quite a different matter. One hundred feet of cutting edge moving 1 foot a minute, is altogether different from 1 foot of edge moving 100 feet in the same time. In the one case a given amount of work is done with 1 foot of



1 foot.

edge, and in the other it is done with 100 feet of edge, the endurance of the cutters in the two cases being as one hundred to one.

This is an extreme illustration of a matter that will be further alluded to in connection with planing machines. The endurance of the edges, or cutting tools, does not, however, become a serious impediment to the action of machines until it falls below three or four inches in length; after which its influence is felt in various ways, such as frequent stopping to replace cutters, frequent sharpening of cutters, their rapid wear, and their imperfect action from crowding the feed, &c., all of which tends to hinder the performance of the machine, and to bring it down nearer to the standard of hand labour.

The proposition would, if followed out, argue the advantage of a great number of cutting edges, when their length has to be limited. In practice we find this the case, a thing that has demonstrated itself in the case of saws, which have the shortest line of cutting edge that is found in any wood-cutting tools. By increasing the number of edges or teeth we attain an aggregate that gives a good result as to endurance. A circular saw 24 inches in diameter can have for slitting from twenty to thirty teeth, which if multiplied by the thickness of the saw will give several inches of cutting edge. The opposite would be to suppose such a saw with one or two teeth only, which would correspond to an ordinary cutter-head.

A planing machine with three cutters, representing six lineal feet of edge, would be an example the other way, in which the amount of edge is made long enough to fill the conditions of endurance. By examining the facts in connection with the operation of the saw and the planer cutters, they will be found to accord with the proposition laid down, and go to establish these general laws which we are discussing.

The third proposition, in reference to the accessibility of the surfaces to be acted upon, is one of the first elements to be considered in estimating the performance, or the sawing effect, of wood machines. It would seem at first to be the same thing as the amount of cutting edge, but in a practical way is quite different.

To illustrate by two familiar examples what is meant, we will first allude to the roller-feeding surface planer, where the lumber is passed continuously beneath the cutters at any desired rate of speed, presenting say in one hour from two to four thousand feet of surface to be acted upon; the material is of such a character that it can be brought to the cutting agents and handled readily either by hand or by power. These we will term conditions that favour the presentation of surface. On the other hand, if we take such operations as cross-cutting forest timber, it is inaccessible, and cannot be brought to, nor passed through machines. From the very nature of the operation it cannot be done by power as cheaply as by hand. In proof we might cite the various ingenious machines for felling trees, cross-cutting them with portable apparatus, and in fact every kind of mechanism that has ever been devised for forest use. We shall find that the chopper's axe has conquered them all, and that unless the element of accessibility is considered in wood cutting, grave mistakes have been, and will no doubt yet be made in attempting machinery which has to adjust itself to the material, and be carried from place to place to perform an amount of work which is really less than that of moving the tools to perform it. Boring implements, all kinds of interior operations, and those that involve cutters of small diameter, come under the same law; their labour-saving result is, however, not to be estimated on this basis of accessibility, because in such cases hand labour has the same troubles to contend with when it fails to employ the whole strength of the workman, and as we have assumed hand labour as a measure of machine effect, it must not be lost sight of in these distinctions.

The fourth proposition, relating to how far machines can be useful, is one that is of great practical importance. There is perhaps nothing in manufacturing that so often leads to mistakes as the want of a true estimate of the saving effect of machines. It is a most natural thing to estimate the labour saving of a machine, as the difference between what it will produce with an operator, and what that operator can produce without the machine, an estimate that is altogether wrong and unsafe. Without following out the various questions that enter

into the relative cost of performing a certain work in the two ways by computing repairs, investment, power, room, insurance risk, danger, &c., we have only to turn to that practical and certain test, *the past history of hand and power performance*, and the effect it has had upon the price of products. The manufacture of furniture, for example, combines a fair average of the power operations of wood work, such as sawing, planing, mortising, tenoning, grooving, &c., &c., and has in fact but few operations wherein power or machines can be applied under favourable conditions. As a rough estimate, the labour and the material in common household furniture is about equal in value, and the saving effect due to machine work must be estimated on the labour alone. Now to go to facts, we shall find in England and in North America that the general saving effected by the use of machinery in this class of manufacture does not exceed fifteen per cent. in its cost, and is much nearer ten per cent. as an average; it is even so little, that in some instances we yet find hand labour competing in the manufacture of chairs, tables, &c., and were it not for the division of labour, carried out by the extensive operations of the manufactories where machinery is employed, the difference would be still less. From these things a tolerably correct idea can be formed of the influence or gain of the machines when applied to the operations in general, and how very likely we are to mistake the value of machinery when considered with reference to special operations, unless we have some rules to guide us in contrasting hand and machine performance.

It must not, however, be inferred that we are arguing the expediency of employing machines from this basis alone; precision and exact duplication may be in many cases more important than the manual labour saved, and have an equal or greater effect in determining the value of a product.

It might even justify the employment of machines, when they enhanced the cost of cutting and shaping material.

The substance of the fifth proposition, relating to the ability to determine from theoretical deduction, or inference, the performance and influence of machines in relation to hand labour, does not admit

of any further consideration than it has received in this and previous articles. It may, however, be said that, granting the truth of the premises assumed, or the truth of others that may hereafter be determined by the aid of further knowledge and experience, it opens up a new field of research in engineering, by bringing the operations of machines within the scope of known laws. It will save millions of wealth in doing away with experiment and mistaken plans. It will harmonize designs, and produce a uniform construction and arrangement of standard machines for cutting and shaping wood and metal.

AMERICAN AND ENGLISH WOOD MACHINES.

Under this head we will notice some of the differences in the practice of wood-machine building in the two countries, that will no doubt have an interest to as many as have not had the opportunity themselves to investigate the matter. It will, besides, afford an opportunity for examining into what we will term the "extraneous" conditions that must, in a large degree, govern the plans for building machines.

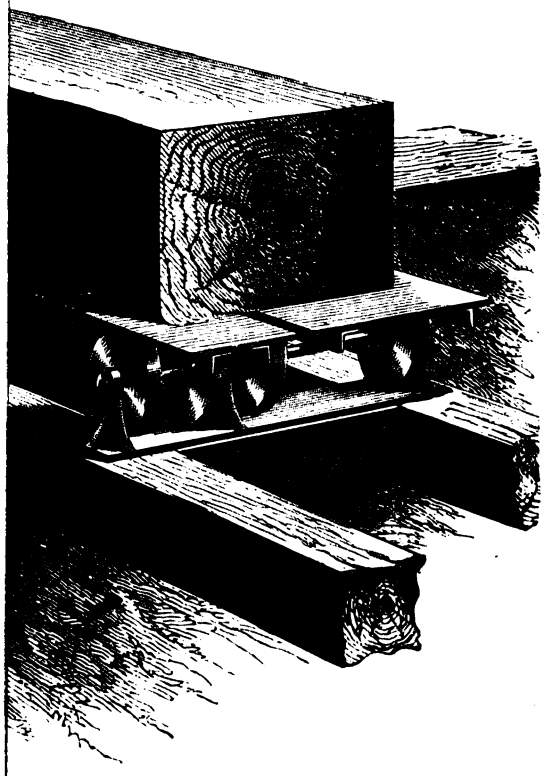
The manufacture in the two countries furnishes extremes of these conditions, and we will give, as we go along, a practical illustration of the ideas which it is intended to present.

The difference at this time (1872) between the wood machines constructed in the two countries presents, perhaps, the greatest distinction that has ever existed in a system of machines both directed to the same, or nearly the same, purposes, and built, as a rule, by those who use the same precedents and the same standards to govern them in engineering matters.

As the wood machinery directed to the preparation of building material represents, perhaps, three-fourths of the whole in America, owing to the extensive use of wood for the purpose, we will, in the first place, consider this class of machines alone.

E XII.

E ELEVATION.)



It should be here noticed that engravings of this class of machines have not been inserted, for the reason that they would have encroached on the limits of the work, to the exclusion of others having a more general interest.

It is not claimed that there is the same amount of engineering knowledge brought to bear upon the construction of wood machines in America that there is in England or on the Continent. This matter has been already alluded to, but the discrepancy in practice is due only in a small measure to this as a cause when it is contrasted with other local conditions which, for want of a better term, we have called "extraneous." It might be said that these "extraneous" conditions belong rather to the commercial than the engineering part of machine manufacture; yet, as the final object of such manufacture is purely commercial, it is proper to consider it in this light as well.

In designing standard machines, where directed to purposes well understood and where new functions are not introduced, it is perhaps correct to say that in most cases the commercial considerations are the prime object, and that the very base of such designs is to attain an equally effective machine at a less cost. These outside, or extraneous, conditions to which we allude can be classified:—

First. As to the nature of the timber or lumber to be worked; whether deep or shallow; hard or soft; green or dry; knotty or clear, &c.

Second. The cost of the machines; the amount of the investment they represent; and the worth of that investment, as governed by local conditions.

Third. The amount and character of the skill to be applied in their operation and care, which is also a local condition.

These several things have relation to the market for which the machines are intended, and account for the difference that we see in machinery that is manufactured in different countries and with reference only to the local requirements of the place.

The first matter—of the nature and dimensions of the timber to be worked—has been briefly alluded to before, but will not suffer from a further consideration here.

A planing machine in England, and in most parts of Europe as well, is generally made to receive lumber up to 12 inches wide, and rarely wider than 14 inches. In North America planing machines, unless arranged for a special purpose, are rarely made to receive lumber less than 24 inches, and often 28 and 30 inches, wide. Here, then, we find in the matter of dimensions a difference that would totally unfit the machines of one country for use in the other; an element, too, that has much to do with the cost and arrangement of the machines. The amount of cutting-edge acting at one time is the exponent for nearly all the proportions of the machine. Pulleys, belts, shafts, gearing, and framing, must all have reference to the amount of surface over which the machine is to act in a given time, or, as before stated, the amount of cutting-edge acting at one time. For this reason we find planing machines for boards, as built in America, twice the size and capacity of those made in Europe. This single local condition of the dimensions of lumber, then, in this case so modifying machines as to double their size, and, if made in the same manner, doubling their cost. We mention this one case in illustration; but the same difference applies in the matter of hard and soft wood, and other things, which will suggest themselves to those who are familiar with wood conversion.

The second condition of cost or investment is governed by the worth of that investment where it is made, and also the length of time the machine will remain in use, which is practically the same thing, for it amounts to adding the principal to the interest after a certain term of use. This last matter of the life of machines has, however, been already treated of in another place, and the question of interest, or the value of investment, is only to be considered here as affecting the construction of wood machines in England and America.

In England money is plentiful—seeks investment and commands low rates of interest. In America money is scarce—hard to obtain for manufacturing investments—and commands high rates of interest.

As an investment, a machine represents at this time (1872) in America twice the sum it does in England. We mean of course

machines that are used in England. This estimate is based upon the annual worth of the investment in manufactures, and supposing the original cost of the machines to be the same in the two cases. If we estimate the difference in the price of material and skilled labour with other elements that go to make up this original cost, the difference would be still greater.

Now this alone is a very strong reason for cheap construction; one of those irresistible influences that defies laws and opinions as well as engineering skill, and is a perfectly valid one for using the least amount of material and fitting, and for cheapening construction in every manner possible without interfering with the essential functions of the machines.

To consider the full force of this matter as influencing machine construction in America, it must not be regarded as a question of investment and interest alone.

The machines are for the most part sold to men of limited means, who have not only to consider the worth of the money after investment, but have first the greater difficulty of commanding a sum sufficient to purchase the machines.

To get started is the object, and the few hundred dollars that can be collected must procure a complete *set* of machines for joiners' work, or a planing mill. After being once started the course is clear. In a few years the machines have paid for themselves; the business has grown to dimensions that warrant a larger and more permanent investment; the old machines are thrown out to be replaced with improvements. This gives an idea of the American market for wood machines during the past.

And while we would not be understood as making the plans and designs of the engineer subservient to commercial conditions, it is argued that these local conditions are among those to be considered in adaptation, and are quite incapable of being controlled by other considerations.

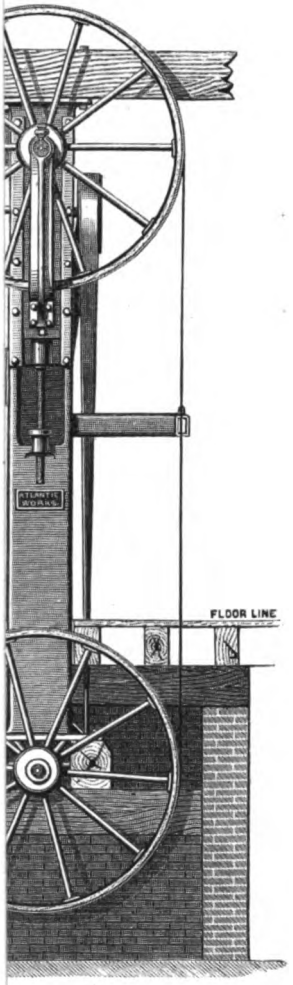
These remarks apply to that branch of wood conversion that we will term joinery, or the preparation of builders' materials, which comprises the greater share of the capital invested in wood manufac-

turing in America. The equipment of railway-carriage works, dock-yards, and other establishments of like character, is different; and while the machines directed to the preparation of building material are as we have represented them, the other class of machines that are now coming into use are as heavy, well made, and even more expensive and durable than those built in Europe.

American machines for builders' materials are made for the American market only, *sold only to those who use them* and understand their use; are never *sold* until they perform such functions as common custom has determined for them; that is to say, the sale of wood machines in America is by custom conditional, the machines are all warranted, and will be returned if not efficient and successful. In England the whole matter is different; the home trade is no doubt subject in some degree to the same rules as in America, but the home trade is but a portion of the whole. Machines are sold largely to mercantile houses for exportation, going to all parts of the world, their greater cost in such cases often being the reason for their selection; the greater the cost the greater the mercantile commissions; we of course do not mean that the same machine would be selected at a higher price for this reason, but that a machine representing the greatest value would, regardless of what such value might be.

The market of the English builder is a general one, and unless machines are made to special order they must be constructed on such plans as will come nearest to a general adaptation.

We next notice in connection with this subject of markets for machines, the very important matter of the skill that is to be employed in operating the machines. This has much to do with making the plans of any machine as well as determining in an indirect way its cost. In America the same reasons that make it the most critical and difficult market in the world to supply with builders' machines, argues the amount of skill that is brought to bear in the operation of such machines. The high price of labour makes labour saving the first and main consideration; cheap construction, bad taste in design, rough fitting, are all lost sight of; it is the quantity



ches wide. *Scale*—$\frac{1}{48}$th, ¼ inch = 1 foot.

elphia, U.S.A.

of stuff that can be "*got* through" in a given time that decides the merits of a machine.

In Chicago, 45,000 feet of pine boards are planed on a single machine (surfaced on one side) in a day; this becomes a standard for surfacing machines, and the manufacturers of such machines must come to this standard; so it is through the whole range of wood machines of this class,—their day's work is known, and to be sold they must perform it. The door and sash machines in use in England, or made for exportation to countries where labour saving is a second or even a third consideration, if brought into such a market as this it would be useless, which proves that this question of skill must modify the character of the machines.

For builders' machines to supply the American market, then, they must be cheap, capable of doing the maximum amount of work when operated with first-class skill.

For the English home market, machines must be better fitted to correspond to the general character of other engineering work. Changes not being so frequent, and the first cost less, they can be made heavier and stronger. The timber to be worked, too, is of a totally different character, which will be noticed in connection with sawing machinery.

For exportation something different is wanted from either of the types noticed, especially when the machine is sent to countries where skill is deficient. The first consideration then becomes, how near can the machine be made to operate without the intelligence of the operator. Second, how long can it be operated without disarrangement or repairs; and perhaps, thirdly, how much work will it do in a given time.

Machines are not made to supplement manual effort or hand labour alone, but also to supply the want of intelligence or "brain power," a proposition that would no doubt have been an absurd one a century since, but certainly a true one in our age. Thus we see that these extraneous conditions have more or less to be considered in machine making. We see the difficulty, even the improbability, of attaining anything like a perfect standard of construction. Yet these modifica-

tions cannot be mere matters of opinion, they must all in time bend to system; and the want of perfect uniformity has nothing to do with, going just as far as we can, in establishing rules and constants, only it must be done with a view to these modifications.

FRENCH WOOD MACHINES.

Without discussing the general merits of wood-cutting machines made in France, it can be confidently asserted that in no other country has so much been done in so short a time, and that in no other country does wood machinery stand relatively so far advanced, when compared with other branches of engineering. There is certainly no other place where it can be said that wood-working machines have attained as much perfection in their manufacture as metal-working machines; a proposition that, so far as the writer can judge, is a true one when applied to France.

The art there is quite new, developed no doubt to a great extent by the International Exhibitions. Ten years ago but few machines were made, and those of the most primitive kind; but now M. Arbey and Co. and M. Perin and Co., of Paris, include among their patterns and drawings nearly all the machines known to modern manipulation, exhibiting a boldness in their design and arrangement that reflects great credit on the enterprise of the makers. Shop manipulation in woodwork is, however, more slow to change in France than in England, to say nothing of America; and the use of wood-cutting machines for many purposes at least, will for a time be confined to large works and the shops of the railway companies. This of course does not apply to Paris, where the finest furniture is made in large quantities, and machinery employed in all operations where it is practicable; nor to any of the large cities, where manufacturing is largely carried on; but to the country, where innovations of any kind are regarded with more or less disfavour.

The engravings from the designs of T. Arbey, engineer, of Paris, which form a large share of those presented, will confirm the statements given. In the German States the tendency or policy is to get a good thing and imitate it, a plan, however safe it may be in a commercial sense, hardly comports with the dignity of true engineering; hence we must say that the boldness and originality of the designs of the French machines presented is highly commendable, and we regret that the nature of the work does not permit of a more critical notice, which would otherwise be given in reference to several machines.

LABOUR SAVING.

This term expresses the leading object of all machines; there are other objects it is true, such as perfect duplication, precision, the multiplication of power, &c., yet labour saving, or cost saving, which is the same thing, is the prime one.

As the term will be often used in the course of this treatise, and as it is advisable to convey by it a correct idea of what is meant, we will here consider its meaning as applied to machines.

The writer, from his personal observation, thinks that the term means one thing in England, and quite another thing in America, when applied to machines. For instance, in England a machine is said to be labour saving when it is automatic, when it dispenses with the labour of the attendant, which is all very well and correct if the attendant can leave it to do something else; but if he has to be idle and watch it, there is a question as to how far this automatic action is expedient. In America the term, as used, means the amount of labour or time saved in doing a given amount of work. Some of the machines considered as the most labour saving involve the greatest amount of effort on the part of the operator. This matter is, however, not introduced to determine the definition of the term, but for the more practical purpose of considering it as a test of wood machines, and how to save

the greatest amount of labour by design and arrangement; how many functions to perform with the machine, and how many to leave to the operator. As a rule, the operator *should always have as much as he can well do.*

It is generally expedient in the way of saving some complication in the machines, to keep the attention of the operator on his machine; besides this, the operator himself prefers it. Nothing is more insulting to the intelligence of a good workman, than to set him to watch an automatic machine, one that does its own work, but yet, from complicity or other reason, needs skilled attendance. In operating reciprocating mortising machines, for instance, the operator can feed the chisel down, or the wood up, and can at the same time feed the piece longitudinally; both these operations require the sense of feeling and the continuous exercise of judgment, in order to do the largest amount of work in a given time, and do it well; yet at first thought we would at once decide that a machine that performed these functions automatically was the labour-saving one; but not so; on the contrary, it is the labour-losing machine, and besides not the one the operator prefers to run.

This principle has its illustrations in what was termed ingenious invention, spoken of in a previous article, cases where the inventor forgets to examine in the beginning whether there really existed a want for the intervention of machinery.

Labour saved means cost saved, and is to be estimated by deducting wages from the whole cost of converting material. It does not mean an economy of effort for the operator, unless the machines are so far automatic as to dispense with his constant attention.

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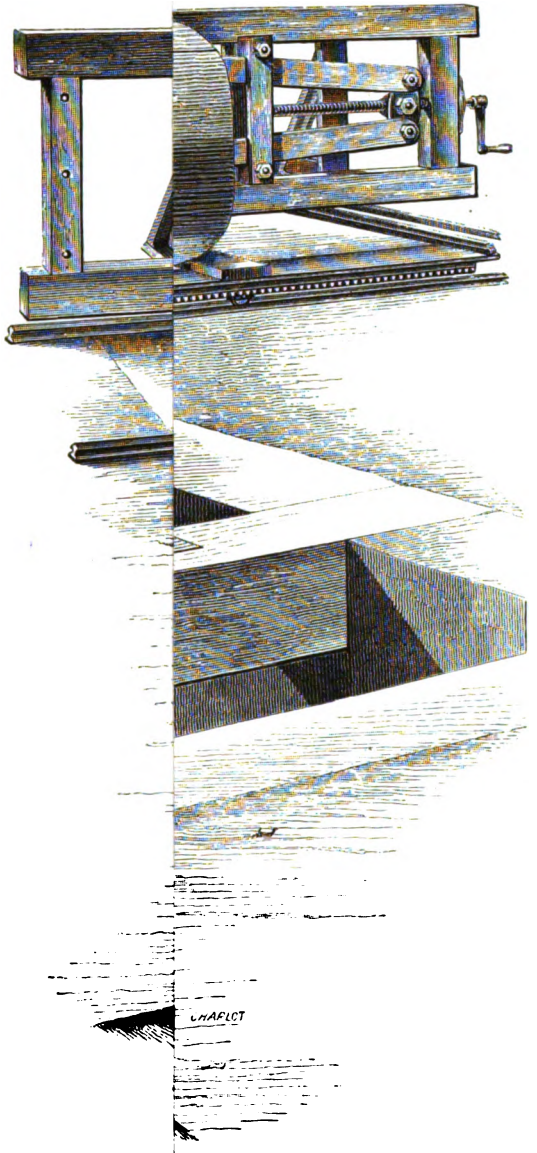

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COMBINATION IN WOOD-CUTTING MACHINES.

Combination of functions, like automatic action, is often misapplied in machine construction, especially in machines for working wood: so long has wood work been performed by hand, and so recent has been the introduction of machines, that it is difficult to do away with the impression that machines are but an adjunct or auxiliary to hand labour, and that a machine which is capable of doing almost anything, and can be called in to assist when needed, is a good thing.

Without assuming that it is not proper and right in some places to have combined or universal machines, it must be maintained that the greatest amount of labour saving is effected by separating, rather than in combining, functions in this way. There is little saved except the framing, and perhaps a countershaft or two, while the capacity of each part is impaired, often but one part being capable of being used at the same time.

There are only two sets of conditions that call for the combination of several functions in one machine for wood work: one, in the case of a very small shop, where *one man* can perform all the machine work; the other case, that of a very large shop, where one man can do the irregular jobs without disturbing the standard machines. In these two places, a machine that will saw, mould, tenon, mortise, &c., is a useful and proper machine, but for regular manufacturing purposes the object should rather be to separate than to combine them.

The large number of machines of this class made, especially in England, leads us to conclude that their sale is created to a large extent by the impression that the purchaser gets a number of machines condensed into one, and at a reduced cost.

The author was once called upon in America to examine and pass an opinion upon a machine which performed all the various operations of making a carriage wheel. He recommended that it be placed in a carriage manufactory for experiment, where it performed in a perfect manner all that was claimed for it, but the inventor was astounded

when the manufacturer told him that he should require at least *twenty-four* machines for his shop, or if he would separate it into some *eight* parts, *three* machines would answer the same purpose. In other words, if the inventor would undo what he had done, separate what he had combined, he would leave the art where he found it, without having added anything. Thousands of pounds in money and time are continually being spent by mistaking "combination" for "invention." The novelty of performing two or more things with the same agent is quite deceptive, and we are apt to mistake for useful that which is only novel.

The courts have done something to correct this idea of invention in combinations, by holding that one or more of the elements in a combination must be new, in order that it shall be proper subject-matter for a patent. Yet patents are continually being allowed in cases where all the elements are old, as they must of necessity be, unless consisting of new mechanical movements which are not likely to be developed by the class of inventors who patent combination machines.

A machine that is arranged to do several different things is generally supposed to do but one at a time, hence the more functions it has, the greater the proportion of that part or parts which are idle. Now machines to pay must not stand idle, they must run, run fast, and run continuously; they must have room in which to handle material, and not be encumbered with parts that have nothing to do with the portion at work.

FRAMING OF MACHINES.

As remembered, it was Sir Joseph Whitworth who first presented the beautiful and appropriate simile between the works of nature as exhibited in anatomy, and the disposition of material in mechanical structures. The bones with their tubular section he likened to the framing of machines, showing that man was but following the lessons

and examples of nature when the material was removed from the neutral axis and disposed on the periphery.

There is here no intention, however, of repeating any of the demonstrated laws that govern this well-understood matter, but only to consider it in connection with the framing of wood machines.

Framing for machinery is made upon two general plans, which we will term *rib* sections and *cored* sections; and as anything relating to the contour or outline form must have reference to some special purpose, or machine, our remarks will be confined mainly to the merits and advantages of these two plans. This is a proper subject for consideration just at this time, when the contest between the two systems may be said to have fairly set in; at least for wood-cutting machine frames.

The framing of wood machines, like that of machines of any other kind, has to be arranged to meet the strains to connect and support the details of the machine, and in most cases form supports for the material as well. There are, however, when we come to analyze the question of strain, so many difficulties to encounter in determining it, that the matter becomes quite complex. The jar or vibration incident to high speeds, although properly classed among the strains that fall on the framing, is an element peculiar to wood machines, and one which there is no constant standard to determine.

In the very interesting paper read before the Institute of Civil Engineers, of London, by G. L. Molesworth, C.E., in 1858, there is mention made of the frames absorbing the vibration from the cutter-spindles. The merits of wood frames on account of their greater elasticity, and consequent power of absorbing the jar and vibration, was admitted by several members who took part in the discussion at the time. The idea is a popular one even now, but that it is a mistaken one, the experience since that time and the modern practice of the best makers fully prove.

That an elastic support for an unbalanced, or imperfectly-balanced, cutter-spindle will absorb and neutralize its vibrations, is unquestionably true, and that such vibration is communicated to the work is equally true. Smooth work being the prime object in most

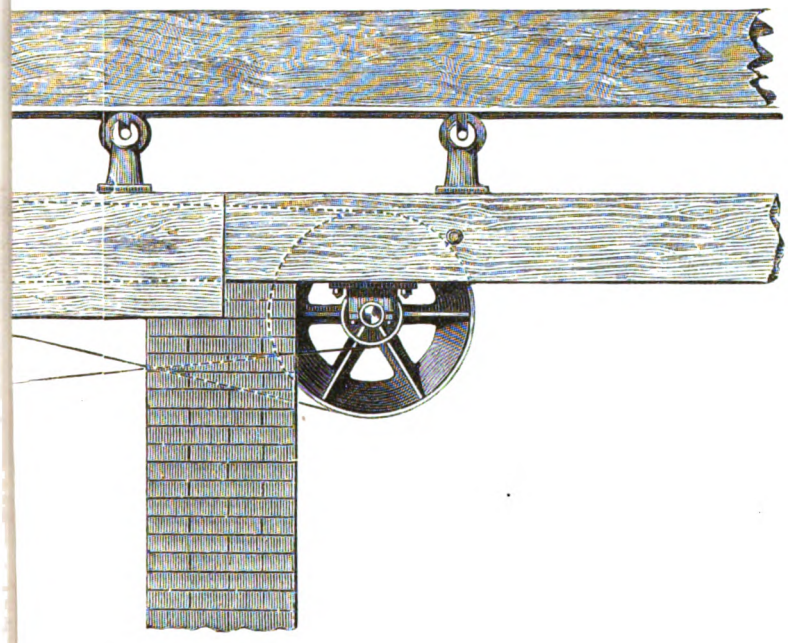
operations in wood cutting, the purpose should not be to absorb the vibration of cutter-spindles by elastic supports, but to resist and destroy it by the most positive means possible. This is a characteristic feature in the best designs for wood machines at the present time; positive and direct resistance to vibration of the cutting agents is the rule. When properly balanced no injury need be apprehended from the solidity of the bearings, which will in practice be found to wear longer than if so mounted on elastic rails, so as to get out of line from the strain of the work, or the belting.

That the vibrations of cutter-spindles can be effectually resisted and best absorbed by rigid framing and supports, is easily verified by an experiment of operating the same spindle under the opposite conditions, an experiment which will not fail to controvert the theoretical influence of the elastic bearings being the best to absorb vibration. In fact, the tremor and jar of such high-speed spindles yield at once to a moderate resistance.

A spindle that is slightly out of balance, running sufficiently loose in its bearings to make a great jar, is, by pressing down the cap of the bearing by hand, at once stopped and without any considerable pressure, at least with but a small share of what would be supposed necessary before the experiment.

In arranging the frames of wood machines then, we will assume, as the first condition to be observed, a solid and firm connection between the cutter-spindles and the lumber-supports, whatever they may be, to avoid the independent jar or vibration of either part. In machines operating with rotary action, the demands of symmetry usually furnish sufficient strength in most parts of the framing; but in reciprocating machines for wood cutting, such as sawing and mortising machines, there is required a strength and arrangement of framing that seems quite exaggerated when considered in relation to the work to be performed.

It is necessary in such machines to not only provide against vibration, but in those for mortising it sometimes becomes necessary to counteract the effect of the reciprocating parts, by the inertia of a mass of metal, having no other object.



Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

In such machines as are popularly known and used, modern designing amounts to but little except new arrangements of framing, the operating elements of the machines remaining the same.

The objects or advantages of such improved designs relate to symmetry, correct distribution of material, convenience of operation, and economy of construction.

The theoretical inference to be drawn from such a proposition would be that such designs would not be a very important matter, yet the very opposite is the fact; the design is everything, the element that determines in most cases the preference of the buyer. Having treated of the question of jar and vibration as affecting the frames of wood machines, we now come to other strains. The frames of such machines are, from the nature of the work and the large dimensions of the material to be supported and handled, spread out over a large floor-surface, and are for this reason subject to a great amount of what we will term "accidental strain," arising from handling in transportation, in erecting, and from the uneven settling of foundations. That this is a novel consideration in machine designing will be admitted, but that it is a valid one cannot be questioned. Machines, if not to be separated in shipping, must have their frames strong enough to stand any kind of rough usage, except a fall from a hoist, and even this would, from its frequent occurrence, be policy to provide for if possible. In fact, the supports, stretchers, and general dimensions of all the larger frames for wood machines have to be more or less governed by this consideration of accidental strain.

If the records of the builders of wood machines were examined, and statistics of the number of machines broken and injured in transportation collected, it would be a very large amount indeed in each year; that such breakage and injury could be guarded against in a large degree by stronger framing there is no doubt: we do not of course allude to a mere increase of section and weight, but rather to its arrangement.

As to settling foundations, the fault is not so much with the builder of machines as with the purchaser and operator; yet in any machine that can stand upon *three legs* instead of four, or more, the responsibility is in a measure with the designer. It is a strange fact

that one of the earliest mechanical impressions that we receive is that a stool with three legs will stand solid anywhere, and one with four will not; yet we have ignored the lesson in machine construction, and as a rule find lathes, planers, sawing machines, in fact nearly all machines, standing upon four legs. An engine lathe for metal work, a tool that is peculiarly sensitive to accidental strains, is always made to stand on four or more legs; the only plausible explanation we have to offer is that the very familiarity of the three-leg principle leads to its oversight.

The sections of framing for machines which was alluded to at the beginning, in the rank of its importance as an element in the designing and framing of machines, should perhaps have preceded what has been already said. The question of the form of sections has to be considered with reference to a great many things which have to do with construction as well as strength. Affecting and governing the form of sections, we have:—

1st. Resisting, transverse, lineal, and torsional strains.

2nd. The economy of material or its relative strength in different forms of section.

3rd. The cost of founding and casting, the amount of skill and labour required in making moulds, and their risk.

4th. The character of the casting as to the strength and integrity of the iron, and the smoothness of its surfaces.

5th. The original cost, care, wear, and changes of patterns for castings.

6th. The convenience and cost of finishing and erecting machines.

7th. Symmetry of design, which is placed last, not in the rank of its importance but because it is invariably a sequence of true adaptation. W. B. Bement, the founder and proprietor of the industrial works at Philadelphia, disposes of this matter in a brief maxim of "whatever *is* well appears well."

Considering the present state of wood-machine manufacture, and the probable changes and modifications of design which can be looked for in future, it will not be amiss to review in a brief way these several conditions as affecting designs for framing.

As to strains: science has long since fixed the tubular form as the best for resisting torsional and transverse strain, in the frames of machines as well as in other structures, yet it is impossible from theoretical inference or mathematical demonstration to appreciate the difference that exists between a rib section and a tubular one; in resisting torsional strain, such as falls upon projecting arms and brackets, the frames of band-sawing machines, &c., it takes practical demonstration to do it. A single experiment fixes in the mind of an engineer a standard of conviction that cannot be reached through calculation. So far as torsional strains there is indeed no argument to make upon sections. For transverse strain the matter is more intricate, or rather it is one not so capable of demonstration by practical experiment. Yet when the parts of machine frames are considered in their several correlations, and with reference to conditions yet to be noticed, it brings us to the tubular or cored section continually as the best form. Tensile strain in machine construction, as a rule, falls upon wrought-iron links and rods, and belongs rather to the operating details instead of the framing.

In a general way the economy of material or the amount of iron needed to give a stated amount of strength, is so nearly the same thing as the question of its disposition and arrangement, that it need hardly be spoken of in a separate way. It must, however, be remembered that the disposition and strength of material in girders and beams, for which our published constants are arranged, is quite a different matter from the framing of machines; and that while one comes within the scope of demonstrated science, the other does not. Hence, while the cost or amount of material is in a general way, as the correctness of its arrangement and distribution, it varies in different cases and in different machines.

The author has in his practice effected in some cases a saving of weight and metal by substituting rib sections for cored ones; but such cases are extremely rare, and have reference rather to the difficulties of casting than to the actual relative strength in the two cases. In band-sawing machines the frames are subjected to a severe strain of a hybrid nature, torsional and transverse, but upon the whole in

a manner to give a fair test of the merits of rib sections and cored sections.

In substituting cored frames for rib frames for three band-sawing machines, Richards, London, and Kelly noted the following facts, which will no doubt be of interest, although they are not given as the result of careful experiment, but as a matter of what we will term shop record.

The relative weight was as five to seven in favour of the cored sections.

The cost of castings was as four to five in favour of the rib frames.

The cost of fitting was slightly in favour of the cored frames. The relative strength and stiffness, which was the prime object of the change, was such as to leave comparison out of the question. The rib frames were weak, and sprung with the tension of the saw; the cored ones could not be moved by the saw, and were perfectly rigid.

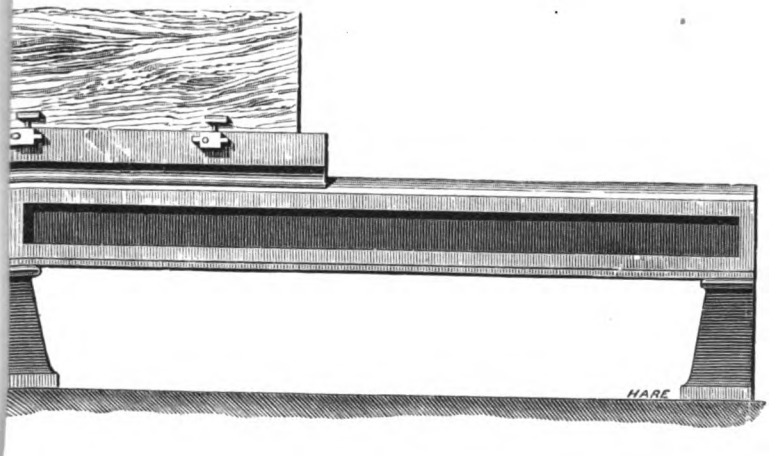
These machines of both kinds are among the illustrations, and it will be seen upon inspection that the throats are much deeper in the cored frames than in those with ribs and web.

In speaking of the rib plan of framing for machines, it may be said that the constant tendency is to make the web thick and the ribs light or shallow. The impression is as a rule, even with engineers, that in the frames of ordinary machines the web or plate is the true frame and the ribs auxiliary, as a means of strengthening this plate; now, however true this might be in special cases, it certainly is wrong for the frames of wood machines when made on this rib and web plan.

The ribs constitute the true frame, and the web, both for economy of metal and to secure castings without inherent strain, should be much lighter.

The web or plate connecting the ribs is no more than a strut or brace, capable only of withstanding strain on its edge or deep section, and contributes, aside from bracing the ribs, but little to the strength or stability of ordinary frames.

The author has, in the construction of such frames, followed for ten years past a rule of making the thickness of the ribs from one-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third to one-fourth their whole depth, and the plate or web one-half the thickness of the rib; or say, for example, in a frame 4 inches deep the ribs to be $1\frac{1}{8}$ inch thick, and the web from $\frac{1}{2}$ inch to $\frac{5}{8}$ inch thick.

These proportions generally leave the casting without much strain, and represent an economical distribution of metal.

Such rules given thus empirically are of course not entitled to the consideration that they would deserve if supported by scientific data; but it is hoped that a long experience will be a sufficient warrant for their recommendation here.

The relative cost of cored and rib frames in the matter of casting is so entirely contingent upon what we will term foundry conditions, that it is quite impossible to make any definite comparison. In a general way, cores represent so much added to the cost of a mould; yet there is at the same time much gained by the facility of getting at the mould in cored work for the purpose of slicking, repairing, and inspection generally, especially if the pieces be contrasted with rib work proportioned as before stated. The mould is, in such work, comparatively inaccessible, except the web, which as a rule does not require much attention except in ramming up.

Foundrymen generally prefer cored work as being of a higher grade, and prefer patterns that are not so fragile as to consume too much time and skill in drawing. In America, unless the work is comparatively much thinner, there is no difference made in price for green sand castings for the class of work we are considering.

The character of the castings in the two cases presents a great difference in favour of cored work, especially as to surface, and we will add soundness, although this might be disputed. In the frames of wood machines, the thickness of the metal is from one-half to seven-eighths of an inch in thickness; with plates of this thickness the metal "sets" almost as fast as poured from its contact with both the mould and core, and there is none of that boiling or circulation that carries all the dirt to the top, and sometimes from a difference in specific gravity gives a different kind of metal on the top and bottom. Castings with cored sections are always cleaner on the "drag side" than if solid.

Another gain by coring castings is their increased strength, from their having a greater amount of mould surface. Of this matter there is no rule to offer nor any special information. We can only say that there is quite an importance attached to it in some of our best engineering establishments.

The patterns for castings represent the dead investment, in machine engineering. They have a continual tendency to get on loss side of the balance sheet, and never do any better than figure in the expense account. In civil engineering work, patterns, as a rule, form an element of the estimates, and may be said to do the same in an indirect way in machine building, yet the safest way is to regard them as expense.

Whatever contributes to the durability of patterns, or to their adaptation in the way of inexpensive change, is a saving which is peculiarly appreciated. As patterns will, however, be noticed in another place, it will only be necessary to say in connection with our present subject, that patterns for cored framing are not more expensive than those for rib work, supposing both to be properly made, and that the solid pattern is durable and the other is not.

Changes are made with greater facility on cored trunk frames, and, what is quite impossible in the other case, the weight of such a frame can be varied with little cost, and in some cases without any cost, by changes in the cores, which require no alteration in the boxes. In long parallel frames there is a decided saving in the patterns by using cores; and if a rib pattern is well made, as it should always be, there are but few cases in the matter of framing where first cost is in their favour.

The facilities that the plain flat surfaces of cored or trunk frames offer for mounting brackets and bearings is no small consideration in their favour; in fact, the ribs of solid frames, to carry them from point to point to meet the bearings and connected parts, are generally distorted so as to destroy the symmetry of the design.

In recommending cored sections for the frames of wood machines, it is intended to include not only such frames as are called stands or columns, but all frames of any considerable size that are bolted up.

Take, for example, the side of a planing machine, where two sides are connected with cross girts. At various points, both inside and outside the frame, there is bolted the details of the machine. If the sides, instead of being ribbed, were made of the same depth and cored, a greater strength would be secured with the same amount of metal, besides the greater convenience of fitting. A slab for the side of a bolted-up frame that is 4 inches thick, if composed of two plates one-half inch thick, connected where necessary with small struts, is much stronger than the same slab if made with a web of 1 inch and ribs of 1½ inch thick. By stronger is meant that it better meets the required conditions of a machine frame as to strength.

PATTERNS FOR CASTING.

No one can be said to be qualified to prepare designs for machines who does not understand moulding and pattern making as well as machine fitting.

A draughtsman who prepares the draught for anything made of cast iron, without considering how it is to be moulded, is liable to grave mistakes.

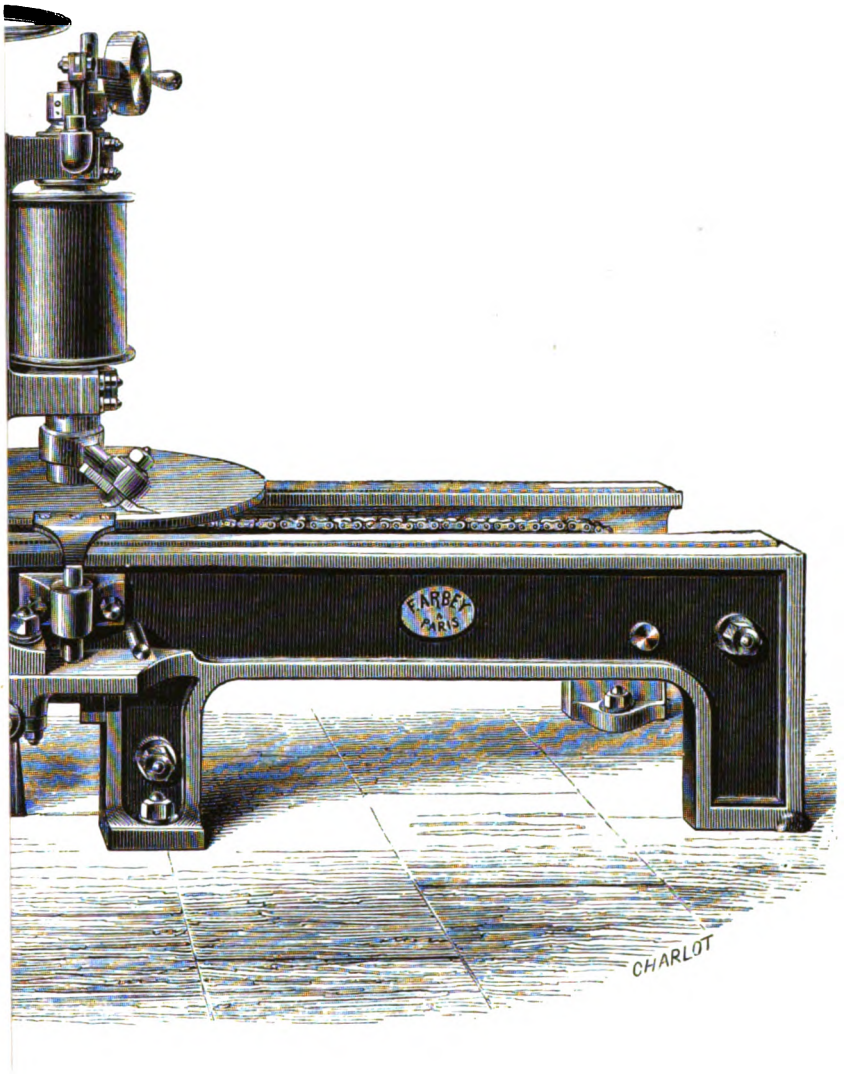
While it would be inexpedient to make designs with reference to the casting of the parts, the two things can be continually harmonized and an economy effected that will make an important saving in the cost of machines. Machines show at a glance, to the skilled, whether the designer understood moulding and pattern making; any considerable error in this way goes far toward neutralizing the effect of graceful curves. As remarked, the design should not be subservient to the convenience of moulding, or the economy of patterns; yet in machine construction, where the same pattern is to be used for a great number of castings, the case is quite different from one where patterns are made for a special purpose; and it is, perhaps, not wrong to say that for the cast details of machines, and for standard patterns generally, the very first element to be considered is the manner of

moulding and drawing the pattern,—where the dirt will lodge, where the planed and finished surfaces will come in the mould, where and how cases are to be vented, and above all the distribution of metal to meet cooling strains. These things are in practice divided between the designer and the pattern maker; their joint knowledge being as a rule more or less at fault, even when coupled with care and long experience.

The immediate object of making machines is the difference between what they cost and what they can be sold for, and engineering knowledge is directed in their construction to two things affecting this matter: their adaptation and their cost. In this cost patterns are the first, and in many regards the main, element, for while fitting becomes conventional, a matter of experience—established by fixed rules and usages—patterns and designs remain more or less one of opinion, undergoing continual change, and dependent upon the knowledge of a few, and without any such fixed rules to guide.

One of the great difficulties in wood-cutting machinery is the casting of the large platens and tables that are needed in sawing and other machines for supporting the lumber. There is nothing in their use that demands much weight, in fact they are in most cases better if light. They should be perfectly clean, and in a state of rest from strains to avoid springing when planed. Such pieces have to be ribbed to give stiffness, which adds to the trouble of their springing. As near a rule as could be suggested for most castings, to avoid strain, is to preserve uniform sections: that is, keep a general thickness throughout; but in the case of tables or "tops," as they are generally termed, the ribs must be heavier. A rib projecting down into the "drag" parts with its heat more rapidly than the plate itself, and should be for average depths 50 per cent. heavier than the plate. To study the means or conditions of a mould, in regard to the conducting of heat during the cooling of the casting, is perhaps the best clue, next to repeated experience, to determine the proper form for patterns.

For wide plates the wood for patterns should be of straight grain, in narrow pieces of not more than ten inches wide, and never "glued



d weight, or guard plate, supported on an axtal shaft passing through

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up;" between the pieces there should be a space of about one-eighth of an inch, to allow of expansion and contraction, which is sure to take place regardless of varnish or waxed surfaces. A pattern when covered up in damp, and sometimes warm, sand is subjected to a kind of steaming process that permeates every joint and pore. They must be framed up with reference to this, and without too much reliance on varnish, which, to the inexperienced, looks like an effectual water-proof protection, but is in fact only a *help* in preserving patterns.

BEARINGS FOR SHAFTS AND SPINDLES.

At the risk of being thought empirical or even wrong, it is intended that in the following remarks on bearings no reference will be made to such rules and proportions for bearings as have heretofore been laid down in text-books. Such rules, so far as known to the writer, are of no use to the constructor of wood-making machines, and in fact are very much at variance with modern practice. When we say that no reference will be made to such rules or tables, it is meant that nothing will be copied from them. It is common in the compilation of works of this character, and indeed proper too, to transcribe as much from former works as possible, which is, however, too often done without considering whether the art has not changed since the original was written.

We are too apt to accept statements from books as trustworthy, that would be scouted if presented verbally, as opinions, from more reliable sources. And it is safe to assume that the greatest amount of information can be imparted by each engineer who writes on any mechanical subject, confining himself to his own experience and opinions, so far as possible.

Bearings will therefore be considered from a shop standard; the views given will be based upon practical experience and observation. It is hoped that what is lacking in science will be supplied in practical suggestions.

Bearings of shafts with slow motion is a matter of little importance; there is nothing to guard against but wear, and whether such bearings be one and three-fourths diameters in length, or three and one-fourth diameters in length, is a question of little moment, so long as the surfaces do not move faster than 200 feet a minute, nor the pressure exceed 100 lbs. to the superficial inch of surface. The bearings of machinery of most kinds come within these conditions, and when it is said that proportions are unimportant, it is not meant that such bearings should not be made to some standard, and that certain proportions are right and others wrong, but that the whole question of bearings must have its greatest and almost its whole importance in connection with high speed or great pressure. High speed is a necessity in wood-cutting machines, and under favourable conditions even is barely a mechanical possibility. The surfaces of bearings in wood machines for the last movers, average from one to two thousand feet a minute, often under severe strain and jar; everything must be favourable to ensure success and have them run without heating.

Such machines comprehend about all that is known or done in high-speed bearings. The movement of cutting tools is from six to ten thousand feet a minute, for which there is no parallel in machines of any other class.

Bearings are, however, much the same wherever used, and the remarks here, although pertaining to wood machines especially, are general in application to high-speed shafts in any case.

First. Will be considered the length and diameter of bearings.

Second. The material for spindles and shafts.

Third. Material for bearings.

Fourth. Compensation for wear.

Fifth. Lubrication.

These things comprehend the main conditions of bearings, and by considering them separately, many things can be noted and said that would escape attention if the subject was treated under a general head.

Assuming a given number of revolutions for a shaft, the diameter of the bearings becomes an exponent of the speed at which it

runs—the rate of surface movement, which is of course the true measure of speed; this makes an argument for small bearings for high speeds, which is all very well if there is nothing to prevent reducing them below the diameter of the shaft itself. Yet for all bearings not at the ends of shafts, it is better to retain the full diameter through the bearing when the speed would not be beyond a practical limit, say of 1500 feet a minute. The advantage is that a solid or non-compensating bearing can be used if wanted: besides, it leaves the position of it optional; it can be set at any part of the shaft or moved at any subsequent time if necessary. For the ends of shafts or spindles, when there is no overhang, the diameter of bearings can be reduced to two-thirds the size of the shaft with advantage; this will form collars or abutments to prevent end motion without in any way interfering with the strength of the shaft. It also adds to the symmetry of hangers or pillow blocks, which always appear to be exaggerated in their proportions, especially such as have a spherical level for the shells. For operating small rotary tools, say of one inch and less diameter, everything must be made to contribute to speed of the cutting edges, which is the great object, and can at best be but limited when compared with ordinary cutting tools. The writer has, in his practice, found it necessary, in constructing machines for "boxing" planes, to reduce the diameter of the cutting tools to three-eighths of an inch. The velocity of the spindles was 12,000 revolutions a minute; which is the highest that the writer has ever known in a regular working machine, yet is entirely successful, and has caused no trouble during six years past, during which time the machines have been in regular use.

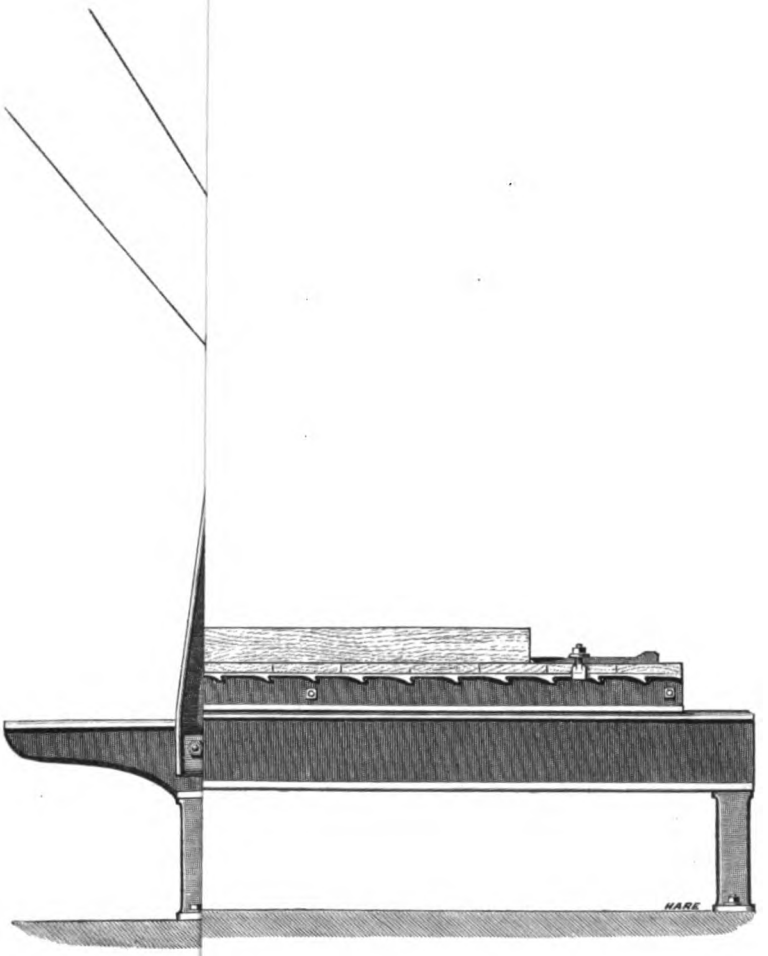
This extraordinary speed was given to spindles, having bearings eleven-sixteenths of an inch in diameter and three and one-half inches long. The spindles were made from forged cast steel, the bearings of alloy (lead, tin, and antimony).

For such high speeds, the spindles and bearings should both be of hardened steel; the bearings as hard as practicable, the spindles with a tool temper (straw colour).

If properly fitted by grinding, there is nothing impracticable in

running bearings of this diameter at 12,000 revolutions, if the pressure is but slight. It makes a surface movement of some 2250 feet a minute. With shafts of rolled iron it is very objectionable to cut them down for bearings; the surface is the most perfect part, and to reduce them usually discloses seams and imperfections. This, however, relates only to bearings in the middle of shafts; for all end bearings should have a welding taken in them, and well set down under the hammer. This not only saves turning in the amount to be cut away, but it expels the slag and impurities from the iron, leaving it cleaner and more easily turned; being on the ends, it does not interfere with centring, which can be done from the undisturbed part of the shaft inside the bearing. In ordinary shop practice the difference between reducing a bearing or other part of a shaft, in other words "necking in" by forging, or by cutting away in the lathe, is regarded solely as a question of time, instead of one of quality as well, especially in working the rolled iron of commerce, which should never be cut down to any considerable depth in the lathe, unless the question of strength is not to be considered.

For spindles or shafts that overhang their bearings, it would of course be wrong to reduce the diameter of the bearing next the "overhang." The shaft or spindle considered as a lever, which it is in reality, has its fulcrum in this bearing, which theoretically should be the largest part. Side head or "overhung" moulding machines are a fair example of this matter. Such machines, although wrong in arrangement, so far as securing the greatest firmness of the cutter-heads, are almost a necessity for reasons of convenience in many kinds of work. The heads project or overhang from four to twelve inches, yet, by a proper observance of proportion and well-fitted compensating bearings, will do good smooth work. The diameter of such bearings should be for shafts of one inch and more in diameter, calling the projection (or overhang) p, the diameter d, $\frac{p}{4} = d$, this will secure sufficient stiffness to ensure smooth work, without jar from the spindle bending. It should be observed that these proportions are without reference to speed, which must be governed by the diameter of the



*Adapte*ree changes of feed forward and back.

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heads, number of cutters, &c.; and will be treated of under a separate head. In practice all the spindles and shafts of American wood machines are too small in diameter; made so either with a view to supposed cheapness, or, as is most likely, from the want of any definite knowledge of what true proportions would be, when considered with reference to the conditions: to govern the diameter of shafts in general, we have transverse strain, distance between bearings, and speed at which they run; the two first in favour of a large diameter, the third favouring a minimum diameter. Belting, gearing, and unbalanced pulleys or wheels represent transverse strain, which must be a matter of judgment rather than estimates. It would be folly to predicate the transverse strain upon a shaft as being simply the tension of belts, or the strain of gear wheels working under ordinary conditions. A rule in the author's practice has been in the case of belts to provide sufficient strength in shafts and supports to tear them asunder, without damage to the machinery. This is the only safe rule, for there is no means of always guarding against winding belts.

Calling the distance between the hangers or bearings b, the diameter of the shaft d, and width of belt w, a rule for ordinary cases would be $w^2 = d$ and $d \times 25 = b$. This is of course arbitrary, and presuming the pulleys to be in the centre between the bearings, and not more than five paces in diameter. In proportioning shafts for belting, much must be left to judgment, and be dictated by that peculiar sense of realizing what is wanted from previous experience. There are in fact so many obscure conditions that have to do with the matter, that any rule must be an arbitrary one, if given for general application. The above is, however, safe, so far as strength is concerned. For gearing, shafts must as a rule be stronger than for belts. The motion is positive, and lacks the elasticity that exists in belt connections. Shafts are in general made strong enough to crush cast-iron gearing; practice has given larger proportions to shafts that receive gearing, no doubt for the reasons stated, that of positive motion, yet the proper plan in the construction of wood machines would in all cases be to drive the first movers with belting so proportioned and arranged that it would be sure to yield before breaking

the gearing. Ordinary belting, with its surfaces dry, as they must be when operated on wood-working machines, has much less driving power than the belting on metal-working machines, when the surfaces become covered with oil or gum, and the leather soft and pliable. Assuming the belts to be dry, a good rule for belting and gearing for feeding wood machines would be as follows :—Let V be the velocity of the belt, and v that of the pinion or first mover, the width of the belt to be the same as that of the gearing $\frac{V}{6} = v$, or in other words, the diameters of the pulleys to be to the pinion as 6 to 1, with equal faces; variations as to relative width should be directly as the proportion between pinion and pulley; if for instance the face of the pinion was reduced to 2 inches, and the belt remain 3 inches wide, their velocities would require to be $v \times 4 = V$, or diameter as 1 to 4, the diameter of the shaft being equal to the square root of the face of the pulley. There would with these proportions be no danger of breaking either shafts or gearing, it being understood of course that in a train of gearing such as is used in planing machines, the force and pitch of each wheel and shaft should be inversely as their velocity.

The length of bearings for high speed is a matter of greater practical importance than their diameter, or is at least one about which there is a greater diversity of opinion, and less obvious rules to determine. That the length of bearings has much to do with their performance, at high velocities, is a matter that no one with practical experience will dispute. In experiments of "starting" up new wood machines at high speeds, a bearing that heats is generally either not "round," or the bearing fit is not perfect; no spindle can be driven at a high speed in new bearings without heating, if it has not been "scraped in" to a fit, which means simply to give it the whole length for bearing surface: the same rule applies to slides. Morin's tables inform us that friction is quite independent of surface and directly as the pressure, which may in the abstract be true, under certain conditions, and within certain limits; but if heat indicates friction, there is certainly something in high speeds that fails to come within this rule. The necessity of long bearings for the spindles in wood-cutting

machines has been demonstrated in the school of necessity, and the fact is so well established that it will be much better in this case to attempt to reconcile the principle with the fact, than it will to controvert what is so evident from experience. The bearings of spindles and shafts in wood machines made in America are, as a rule, much longer than they are made elsewhere. The system of casting in a soft metal lining which is, outside of a single firm, almost a uniform practice, may have something to do with this. Bearings so made are easily got in line, and the expense is but little increased in adding length; besides, the exclusiveness of this branch of machine manufacture before noted has prevented the adoption of the proportions observed in steam engines, mill-gearing, &c.

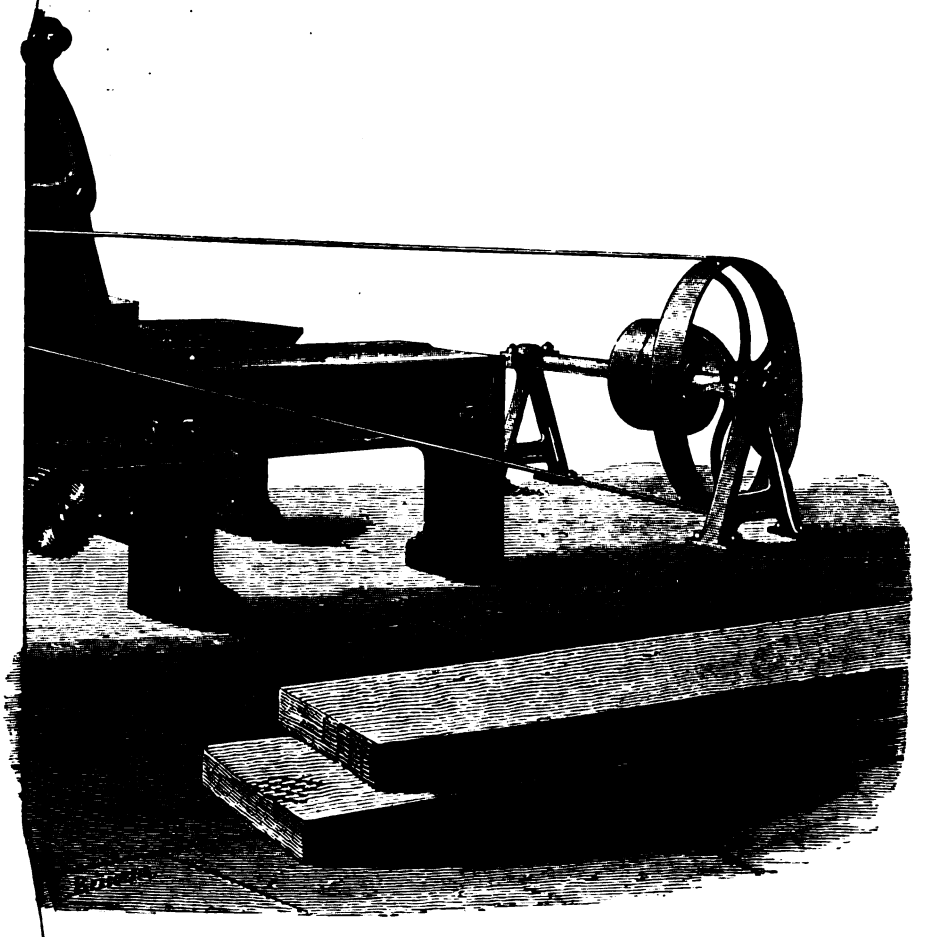
The rule, however, is not restricted to wood machines alone, for the bearings of a line shafting are made even longer in proportion.

Messrs. Wm. Sellers and Co., of Philadelphia, who have given more attention to the subject than any engineering firm within the author's knowledge, make the bearings for line shafting *four diameters in length;* and their long and successful experience in this branch of work is a strong argument in favour of their proportions, which are carried out with great exactness in every particular. Such bearings must, however, be pivoted in all directions, and adjustable independent of their supports, otherwise such long proportions would be open to serious objections, both as to the expense and trouble of erecting, and afterwards keeping them in line. For wood-working machines the bearings when of brass should, for speeds that exceed 300 feet a minute, be three and one-half diameters in length; if made with soft metal lining, four diameters in length is a better proportion. This would of course include the lips at the ends of the bearing, which, if not bored, cannot be included with the bearing surface, and would diminish the actual length of the bearing surface the extent of their breadth, usually one-fourth inch at each end. The same proportions will be found long enough for bearings with annular dripping cells at the end, in what are termed self-oiling bearings, as the better lubrication will fully compensate the loss of surface.

Solid bearings for the ends of countershafts, when the shaft is much reduced, should be longer; in fact the rule would not be far wrong if based upon the general character independent of reduction for bearings.

The material for spindles in wood machines, like everything else that has to do with operating at high speed, is of great importance. A short time ago there was not much choice in this matter, iron being the common and only material; but at the present we have all grades between the common rolled iron of commerce, and hammered cast steel. Rolled steel has become the standard material for spindles and shafts of wood machines. It presents many advantages over iron, being more homogeneous, a quality that ensures round or cylindrical turning, which of all other conditions has most to do with bearings running cool at high velocities.

A shaft may be ground "round" by light contact, if the material is irregular as to hardness, but it cannot be made so by turning and filing. This peculiar feature in turning, although of course one well known to the workshop, is never understood nor realized except for high speeds. A latheman may spend his life in turning on ordinary work without meeting any of the peculiarities that will arise in the bearings of wood-cutting spindles. So important is this that it becomes a kind of "secret" or exclusive work in most shops engaged in the business. An old turner accustomed to the work will, by placing his hand upon a bearing that is running at a high speed, at once detect any want of truth in the turning, an evidence of the extreme sensibility of touch, which is the finest of the senses. Steel, as remarked from its homogeneity, is better adapted for spindles than iron; it is not only more easy to turn true, but from its superior stiffness the shafts can be made of less diameter, the difference in practice being about one-third. This is alone a sufficient reason for its employment in all cases, on account of the reduced speed in the bearings to which, as before said, everything should contribute as far as possible. Assuming that there is a difference of one-third as to stiffness and strength between the common rolled steel and iron of commerce, there is of course but little difference as to cost



y wheels for grinding the cutters without removing them.

between them, and as steel is fast superseding iron even where there is nothing but constant tensile or transverse strain to contend with, it would seem superfluous to recommend its employment for shafts in machines.

In wood-cutting machines there is in many cases a necessity for what is technically known as "overhung heads," cutter-spindles that project to receive cutter-heads outside their bearings.

Overhung moulding machines, the vertical spindles in planing machines, and the spindles of shaping machines belong to this class. In such cases the rigidity or stiffness is of the highest importance, not only to ensure true motion and smooth cutting, but to prevent influence on the bearings, which is soon manifest if the spindles spring or bend, even in the least degree. For such uses or such places, steel should be used that is not annealed, but what is termed crisp and hard.

A good plan is to cut off such spindles in the lathe with the "steady rest" without heating the bars, which are as a rule, if not reheated, about right as to temper and hardness when they come from the mill.

Spindles that are hardened should be of forged cast steel; not that there is anything gained in texture or homogeneity over rolled or machinery bar, but it is less disturbed in the process of hardening, and does not require so high a degree of heat. A good rule for steel spindles for wood machines is to keep them out of the fire, cut them off cold, and turn them without annealing. We are quite aware of how far these plans may be open to the criticism of the scientific, and that they may vary from rules for practice laid down upon the ordinary data: yet they are based upon a long experience, and have certainly the claim of having been tried and found good.

The cold rolled iron manufactured in America gives astonishing results as to stiffness over the common hot rolled bar, and if it were as straight as it is round and stiff it would be an excellent substitute for steel for countershafts, or first movers, in wood machines. It is a matter of astonishment how very truly cylindrical such iron is made, in fact nothing but demonstration would prove it to anyone's

mind. If the process is one that is susceptible of the usual improvement by experience as to both the quality and cost, such shafts may in many cases take the place of turned ones. For line shafting it is largely used in America, its torsional strength being rated in general at one-fourth more than turned shafts.

In speaking of shafts for wood machines it will, at the risk of being unscientific, be as well to say that results arise somewhat at variance with the authorities. A shaft or spindle of soft iron when mounted in cast-iron bearings, for instance, will run better than one of steel; that is, it has a less tendency to heat when the pressure is inconsiderable. This fact has no doubt been noticed by others, and may be due to a greater difference between the molecular structure of the two materials, than as between steel and cast iron. It is merely mentioned as a curious fact that may have something to do at times in the arrangement of machines.

The material for bearings which will next be noticed is one about which there would seem to be but little difference of opinion if we examine what has been written and the results of experiments; yet we find in wood machines at least a great diversity of both practice and opinions. In England the bearings for wood machines are generally made of brass fitted in planed seats or with bored bushings, when compensation for heat is not needed. In America the bearings, the spindles, and shafts of wood machines are almost always of soft metal, melted and poured around the shaft or a template into annular recesses formed in the casting to receive it. A few firms use brass borings for the main cylinder of planing machines. Richards, London, and Kelley, of Philadelphia, make all bearings of steel, brass, or cast iron. With these exceptions "bobber metal" bearings, as they are termed, are the rule for wood machines. Considering the manner in which such bearings are made, the character of the alloy used, and the object, which is cheapness, there is no question as to their inferiority to brass or cast-iron bearings. In the cheaper class of machines not a bearing is bored; they are first poured or moulded around the shafts, and the planing then done from the shaft or spindle, and from the rapid wear in such cases its position is an uncertainty after a few weeks' use.

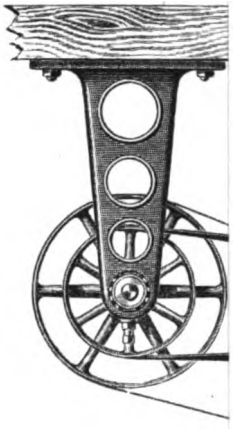
The nature of the alloys offers such a temptation to cheapness that the whole system as at present practised has nothing to recommend it.

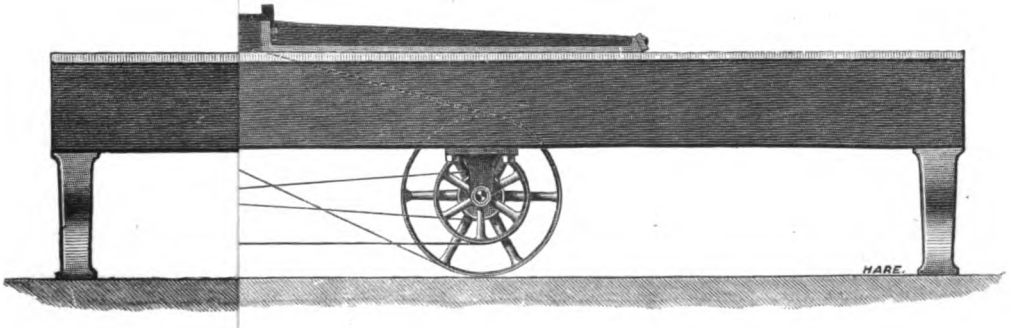
A bearing made of copper and tin alloy of proper hardness, poured into the casting, then well *hammered in and bored*, is beyond question one of the best for high speeds; and the common use of alloys, in making the bearings for steam-engines and locomotives is an evidence of its merits under certain conditions. But in regard to wood machines in general, it may safely be assumed that unless such bearings are made in a manner that costs even more than brass, they have no special claims to recommend them in practice, while there are serious objections to them in the workshop in the way of danger from fire, danger from explosion in pouring them, taking attention from the ordinary course of work, and, most of all, the difficulty of inspecting them with any certainty after they are finished. The metal may be loose in its seat by contraction, yet this will not be manifest until the spindle is set at its work and does it imperfectly.

All things considered, it is perhaps safe to assume in reference to "moulded bearings," which is a better term for them, that they should, in the manufacture of wood machines, be confined to the cheapest class of solid or non-compensating bearings, when the movement does not exceed 250 feet a minute. Tempered steel bearings, considering their expense and the difficulty of fitting, cannot be recommended for any, unless very special, cases; it is better to trust to larger surfaces of brass, cast iron, or alloy. It is difficult at the present time to account for the old plan of stepping a vertical spindle, by reducing it almost to a point, and then mounting it in hardened steel, its two ends representing opposite theories under the same conditions, except the end-thrust being taken up in the lower bearing. This plan of hardened point bearings for steps, the end of lathe spindles, &c., has been until very recently the general plan followed by all machine makers, and accepted as a sound principle of construction. Experiments, however, in supporting turbine water-wheels, and in resisting end-thrust of propeller-shafts, have introduced a new plan of "increased surfaces," composed of such materials as give good results in ordinary bearings.

Wm. Sellers and Co., of Philadelphia, have in their practice adopted a plan for stepping vertical shafts, that is almost the very opposite of the old point theory, that of wide, flat, surfaces. A disk, or collar, is formed on the end of the shaft, resting on a corresponding plane, in the face of which there are radial curved oil-grooves, the action of which corresponds to the furrows in the faces of mill stones; the oil is fed to these surfaces through a central opening, and discharged upon the periphery, returning through proper channels to the reservoir, to be again taken up. This for heavy thrust and motion that is comparatively slow is no doubt as good a plan as can be adopted for the ends of shafts. It is, however, inapplicable to wood-machine spindles, in fact is not needed, as there is seldom any pressure beyond the mere weight of the spindle and its cutter-head.

The Schiele curve is no doubt the true form of bearing to resist end-thrust with high speed, either for end or central bearings. The great fault in all bearings, when the plane of the surfaces is transverse to the axis of motion, is that they move on each other at different degrees of velocity, varying from the centre to the periphery, directly as the diameter. Here then we have the violation of a simple principle of construction, surfaces working under the same conditions, with uniform capacity for resisting wear, lubrication, and compensation, but moving at *different velocities*. In this is found a sufficient explanation of the, to many, puzzling fact, that end bearings are apt to heat, and wear, although seeming to be the most durable and simple. The Schiele curve of equal tangents is a theoretical, and for that matter practical attempt, to obviate this infraction of mechanical principles, by taking up end-thrust on surfaces having a uniform connection for resisting wear. Its importance as a principle of construction in machines has never been appreciated, at least, in common practice; there is no doubt of its correctness in theory, and but one result in its application. Messrs. Bement and Son, of Philadelphia, and Messrs. Brown and Sharp, of Providence, America, have introduced this bearing in many of their engineering tools, but in wood-cutting machines no application has, until very recently, been made.



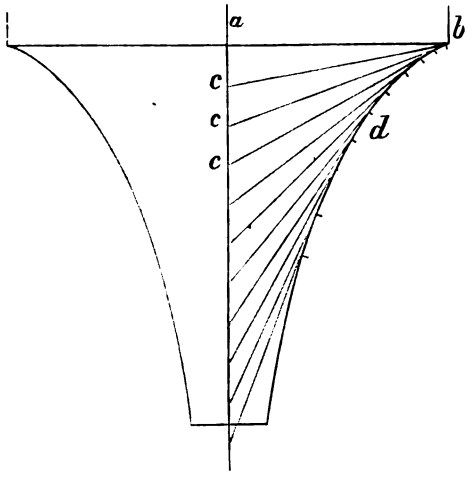


ut of wind, three sides at one time.

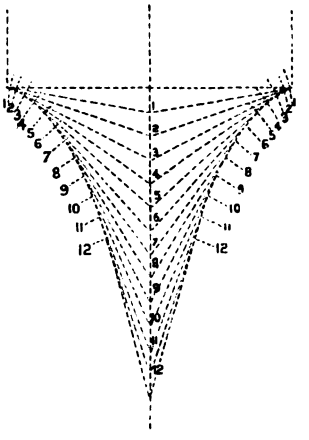
lelphia.

We introduce the following diagram, showing the plan of generating the Schiele bearing.

MANNER OF GENERATING THE SCHIELE CURVE.—FIG. 1.



EXPLANATION.—Set off the points *c c c* on the axial line, ten or more in number; take the distance *a b* in the dividers, and from the points *c c c* set off this distance on the preceding line; this gives the points at *d* through which the curve is drawn.



EXPLANATION.—Lay off divisions on centre line; first draw line from diameter to first point; with this point as centre strike radius on said line; from point thus obtained draw a line to second point on centre line; again strike radius, and continue as before.

It is quite unnecessary to follow out the curves to the standard laid down; it is, however, obvious that the advantages will be directly as we approximate to the true curve as shown. When the weight of spindles is to be carried on collars, for instance, as is very often the case in wood machines, the plan can be carried out as far as practicable, so as not to reduce the spindle below its continued diameter, through the bearing. As a rule anything is better than flat radial surfaces at right angles to the axis of motion, when there is but a limited amount of surface. A better explanation would be to say that any portion of the bearing can be used by beginning at the top, following its lines as far as possible. The writer has in his practice found no difficulty in supporting the spindle and heads of transverse planing-machines, weighing from 200 to 400 lbs., on collars representing less than one-fourth of the diagram, the extreme diameter being 4½ inches, the

spindle making from 15,00 to 18,00 revolutions a minute; bearings of brass (six parts copper, one of tin).

To resume the subject of the material of bearings, it may be remarked that the claims of cast iron are not generally understood; we mean of course in the workshops and among machinists, especially among the makers of wood-cutting machines. In America it is scarcely ever thought of, and in England seldom used; yet there is no question as to its being the most durable, and in some regards, the best possible bearing for high-speed spindles. For hardened steel spindles it is almost equal to a hard steel bearing at moderate pressure, and is much cheaper. As remarked before, however, there are many conditions to be observed by the designer of wood-cutting machines besides those which apply to other machines, or to machines in general; and while cast-iron bearings in wood machines are in some cases preferable, and to be recommended, they require a degree of care in fitting and afterwards in operating, that renders their use inexpedient, except in special cases. Bearings in wood machines, from high speed, the absorption of oil by dust, and the "grit" that unavoidably gets into the bearings, are continually liable to cut, or abrade. This fact is sufficient to give us the general rule of making the bearings of material softer than the spindles or shafts, so that in case of abrasion the least valuable part is destroyed, and the evil more easily remedied. This, in fact, is the great argument in favour of the soft metal moulded bearings in American wood machines; the spindles are safe, and anyone can renew the bearing. No one is considered in America a competent operator of wood machines who cannot remove the bearings of his machine. That such abrasion need take place is contrary to the opinions already given, and that it is contingent upon the original construction of the machine in a great measure, is true; but so long as American wood machines are made on light frames, with minimum proportions in all parts, the "bobbet metal" bearings are perhaps not far wrong. Glass, wood, raw hide, and other materials, have been employed for bearings in wood machines: all of them may have their peculiar merits under certain conditions. Wood, for instance, is unquestionably better than metal for one of the surfaces

of a bearing that cannot be lubricated; a kind of bearing peculiar to wood machines, and which requires the most careful consideration. For instance, the bottom girders of reciprocating saws, especially the scroll saw, and the "muley type" of lumber saws, the lateral guides for circular-saw plates, and band-saw blades. Such bearings cannot be lubricated, or rather kept lubricated, the oil being instantly absorbed by the dust, or carried off by contact with the timber.

In such places there is nothing in the writer's experience that recommends leather or raw hide, although often used in American muley mills. Wood is the best material for such bearings, and if properly arranged to work with polished surfaces of steel or cast-iron, its durability is remarkable. There is, however, a vast difference as to the kind of wood used, which must be selected with reference to porosity and hardness; such varieties as readily absorb oil and yet are hard, are to be preferred; with end contact apple and pear wood is the best, especially when steamed in seasoning, which drives the gum from the pores, and leaves a system of capillary tubes to retain and diffuse oil. Ash or oak "weather seasoned" is totally unfit for such uses; as well as every variety of fir wood, when it contains pitch.

Wood as a material for bearings, aside from cases when the oil is absorbed, is a good one when *contact between the surfaces is intermittent*, such as long slides with short bearing blocks, and considering its safety from abrasion, its cheapness, and the facility with which it can be renewed or repaired, it has much to recommend it for the guides of saw frames in lumber mills. So thoroughly has this been demonstrated in practice, in the forest mills in America, that metal bearings for guides are rarely met with. It has even been employed by some of the best makers for the cross-head bearings of steam-engines, giving, as is claimed, a good result with little or no wear upon the guide bars. In all bearings, however, where there is continuous contact between the surfaces—in other words, all rotary bearings—there is nothing to recommend wood or any other known material in preference to metal.

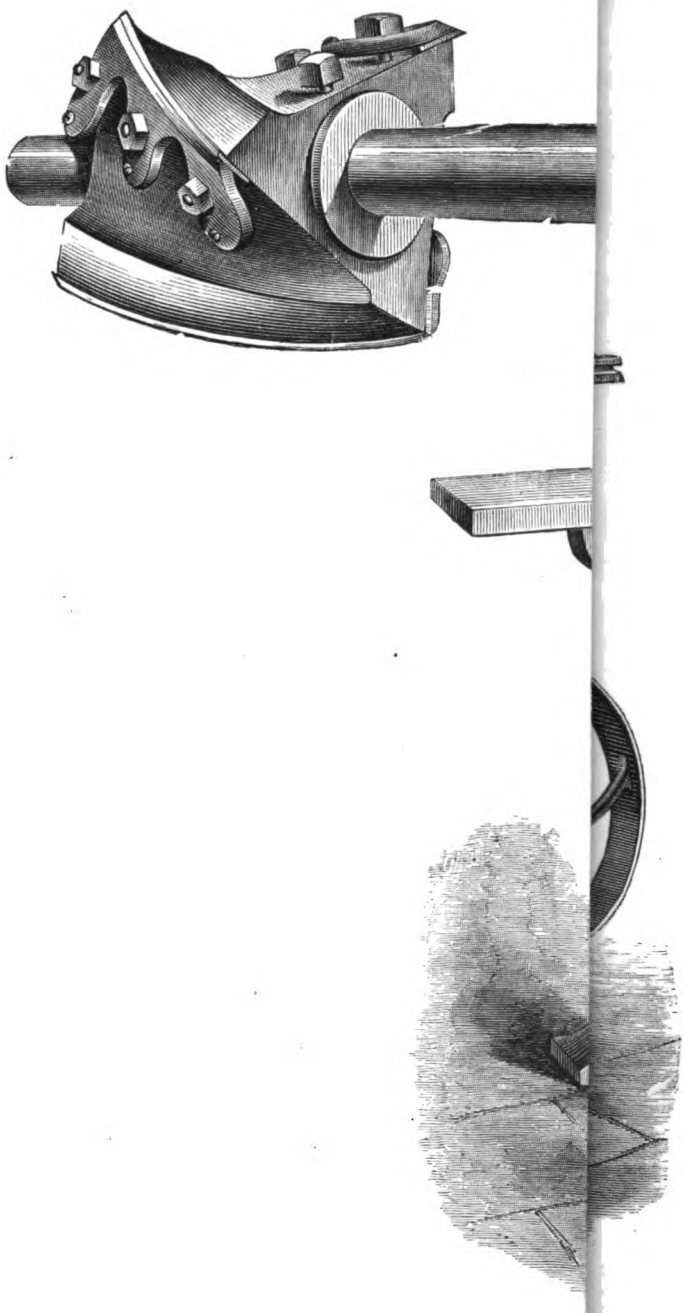
In 1865 the writer constructed some bearings of coiled wire that for vertical shafts gave a good result. The process was as follows: the spindles were placed in a lathe and the bearings

tightly wound with No. 16 brass wire; the ends were then fastened, the spindle placed in its seat, and an exterior bearing of zinc run around the brass wire. The spindle being tapered, was then removed, leaving a matrix with a helical thread formed by the wire, which was so wound that the volution of the spindle tended to carry the oil upward from the bottom where it was supplied. The first experiments were unsatisfactory from the "hair line," or limited contact of the wire with the surface of the spindle, but after using a pressing roller that flatted the wire in winding, a good result was attained, with a very cheap bearing. It was good especially in regard to lubrication; the action of the helical groove seemed to nearly balance the gravity of the oil, which remained in the bearing as long as though in a horizontal position.

Compensation for wear in the bearings of spindles of wood machines should be for those carrying cutters of the most perfect character. If it were not for the heat generated from high speed and consequent expansion, solid or more compensating bearings could no doubt with proper fitting be used in many cases, and relieve the operators from the care and experience that is needed in adjustment, but the best plan is, in all cases where the speed exceeds 250 feet a minute, to make the bearings in two halves, or with conical bushes having end adjustment. That the old traditional two part brasses are often employed when other forms of compensating would be as good or better, is no doubt true, yet the simplicity of the plan, and the fact of its being so generally understood by operatives, make a strong argument in their favour.

In wood machines there are two conditions opposed to each other that render the bearings of spindles the most difficult to take care of; the high speed demands them to be *loose*, the cutting, on the other hand, requires them to be run *tight* and close.

Between the two there is a mean, attained only by the best of fitting, which constitutes the true standard; there is no question that the spindles of lathes, milling machines, gear engines, and other metal-cutting machines demand the greatest possible degree of steadiness in their supports, *but there is nothing to hinder it.* Start one



Arranged with Vertical Spindles for Edging, and w part of,

of these spindles at three thousand or more revolutions a minute, and a new set of conditions arise; the bearing and fitting that was well enough at as many hundred revolutions in the same time will be all wrong as to proportions, material, means of compensation, lubrication, &c.

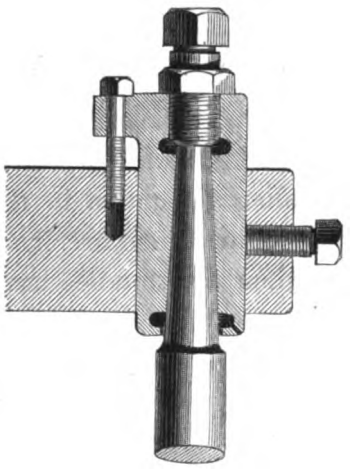
An end adjustment against a Schiele bearing, for compensation, would soon become fast by expansion in the length of the spindle, or would, when the spindle was cool, be too loose to do its work smoothly. Hence bearings of this kind, which have peculiar adaptation in the case of ordinary metal-cutting and other accurate machines, are inadmissible in wood-working machines, at least when the spindles have any considerable length.

Semicircular boxes, closing as solid halves on a spindle, have too their objections. They do not close concentrically, and do not in many cases fit the shaft, that is, they do not fit with the precision that is needed to maintain what we will term "capillary lubrication;" besides, the wear is generally through the strain of belts on one side or in one direction affecting the line of the spindle; yet, considering all things, they are the safest and best for all inside bearings, as distinguished from those at the ends of spindles. They should, however, whenever practicable, be parted transversely to the line of strain upon the spindles by the belts. The force of the cutting need hardly be considered.

Conical compensating bearings should, in wood machines, be long, have as much surface as any other kind of bearing, and never be depended upon to resist any end thrust, no matter what their angle or degree of taper; we, of course, do not allude to the Schiele curve bearing, but to what is technically termed a straight taper. Such bearings should pass through the shell, and rest against an adjustable screw, of hard brass, having a core diameter equal to that of the spindle. Surrounding this bearing, between the end-thrust screw, as it may be termed, and the spindle, there should be an annular cavity for oil, filled if possible with fibrous packing; by giving the shell an adjustment on the spindle, and arranging it to be turned in its seat, such a bearing becomes one of the best for high speed. The

combination of the end screw with the end adjustment of the sleeve constitutes a very sensitive and accurate adjustment, which the end expansion of the spindle cannot affect; besides by rotating or changing the sleeve the bearing is kept concentric and the spindle in line. The writer has in his practice applied bearings of this kind with great success to turning lathes and the vertical spindles of moulding and planing machines, in fact, whenever the end of the spindles could be so mounted, and has never in any case failed to have better results than with open or parted bearings. Their special application to vertical spindles, as a self-lubricating step, originated the idea, which is no doubt an old one in machines of other kinds. A central vertical section of a bearing of this kind is given at Fig. 2 for a spindle one and one-half inch diameter to a scale of one-fourth.

Fig. 2.



In regard to the lubrication of the bearings of wood machines we must, at the risk of the remark becoming a hackneyed one, say special arrangement is needed. Nearly every bearing in such machines is continually undergoing a robbing process by means of the wood dust, which is a great absorbent of oil.

This fact, coupled with the extra amount of oil needed on account of the great speed, fully justifies the above remark.

The destruction of a bearing for want of oil is not a process, but at high speed is the work of an instant. Spindles revolving at 4000 revolutions a minute will, if they become dry, stop as quickly as though the section of the bearing had by some magic process become rectangular. The lubrication of such bearings is not only, as remarked, of special importance, but certain obscure conditions arise that might almost be classed as phenomena. One of these curious circumstances came recently to the writer's notice in his own works, when he was applied to for an explanation of the fact that in a new

machine started for experiment no oil would enter the bearings. The spindles, $1\frac{1}{16}$ inch diameter, were making some 2500 revolutions a minute, in bearings of brass, 7 inches long, having a central inlet for oil drilled through the shell and communicating with helical grooves for distribution. The oil when poured in was ejected with an appearance of being blown out by force. The manager accounted for it from the position or direction of the oil-way leading to the bearing, which upon examination and change confirmed his views. The front side of the hole, technically speaking, was on a radial line from the centre of the shaft, and for reasons which would hardly seem sufficient for the result, the oil was ejected. A slight change, so that it led in the direction in which the surface of the bearing was moving, produced an effect just the opposite. The oil was drawn into the bearing with an inductive force that suggested a pneumatic vacuum. This is alluded to as one of the apparently trifling things which in most kinds of machines have no importance, and yet in high speeds cannot without serious results be neglected. It was of course contingent upon the speed of the spindle, which either by centrifugal, or some strange capillary influence, attracted or repelled the oil. This peculiarity is illustrated in a special kind of bearing for shafting, patented and manufactured by Lane and Badley, engineers, of Cincinnati, United States. There is below the matrix of the shaft an oil-cell formed in the casting from the bearing, and communicating with this oil-cell are drilled a number of small holes, say, not more than one-sixteenth of an inch in diameter. These holes, although we are not able to assert the fact from personal knowledge, are no doubt drilled so as to meet the conditions of the experiment just described.

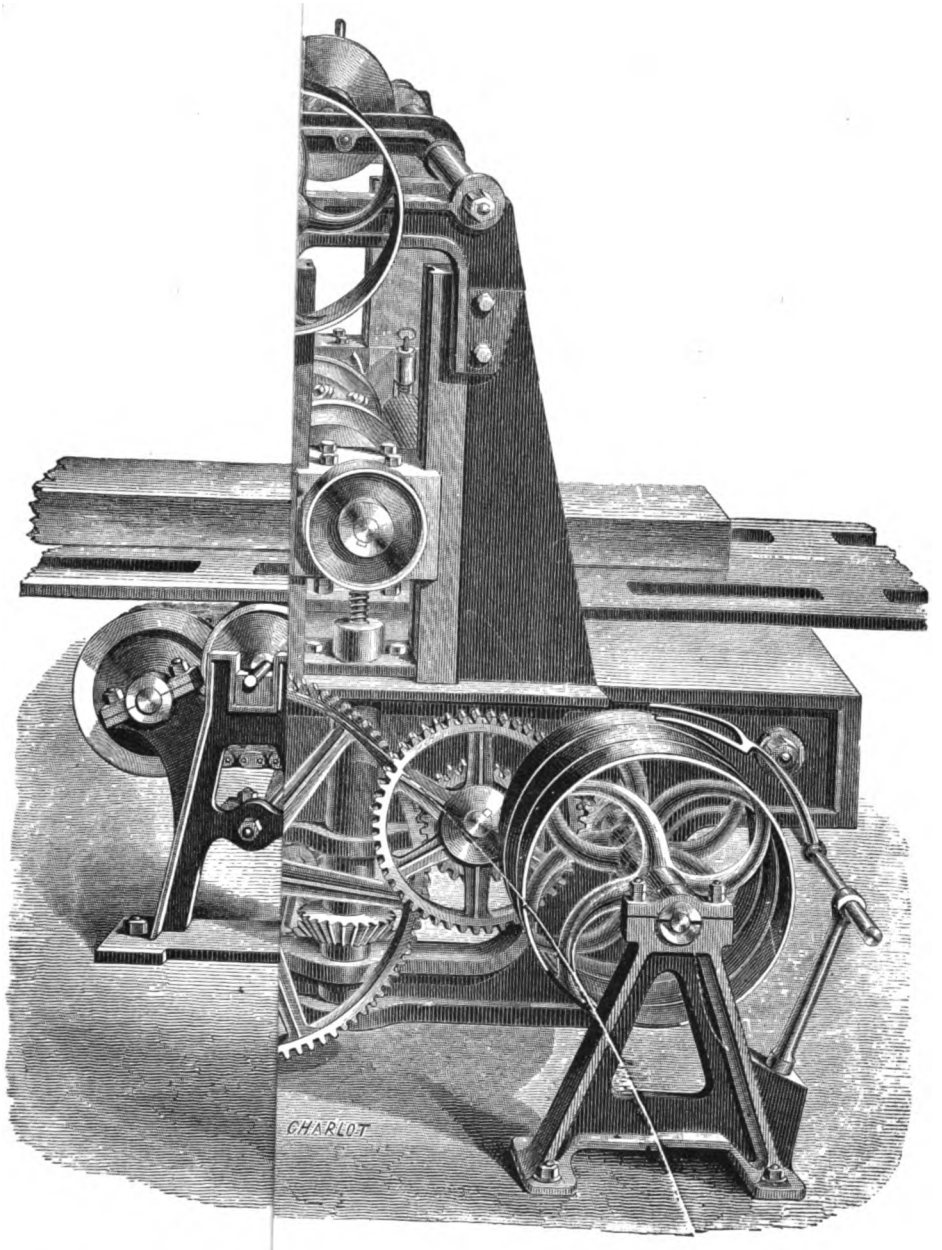
At the ends of the bearing proper there are the usual dripping cells, communicating with the oil-cell mentioned, for the return of the oil after it has passed through the bearing. Now the practical result is that the oil is by this same mysterious process drawn rapidly up through these small holes, and circulates through the bearing at a rate much more rapid than can be attained with fibrous feeding wicks. Its excellent adaptation for the bearings of line-shafting has been

very fully demonstrated by the firm, who make a specialty of work of this class, and whose engineering ability is quite sufficient to confirm its merits as a plan of lubrication.

The idea of oil-cells in connection with bearings, having feeders of fibrous material to the bearing, and end cells to catch and return the oil, like many other improvements in machinery, has no doubt, in wood machines at least, been carried beyond what is demanded.

That "self-oiling" bearings, as they are termed in America, have been applied in places where they had better been omitted, a little reasoning about the matter will confirm. In machine fitting such bearings were first applied to saw-spindles—or "mandrils," as they are generally called—and from that were introduced in nearly all kinds of wood-cutting machines for the bearings of shafts and spindles. The result in practice is, that those who operate the machines oil just as often as though the bearings had not the oil-cells; and properly too, for no careful operator can trust to any kind of lubricating device that will first indicate the want of oil by the heating of the bearing. Such spindles and such machines as require constant attendance do not need such bearings; they tend to carelessness on the part of the attendant if he relies on them, which is not often the case. If he does not rely on them to lubricate themselves, they are of no use; and, in practice, there is no question of the propriety of leaving the responsibility of oiling, at least the main spindles, to the operator. For slow-moving shafts, and, indeed, in all cases where there is not constant attendance and personal supervision, bearings should have some plan of constant lubrication, either by the thermatic or wick plans.

In forming oil-cells beneath the shaft, with wicks to feed to the bearing, such wicks should not be set merely with their ends in contact with the bearing; annular grooves should be made around the shaft, communicating with the oil-cell, the wick *put around* the shaft, with its ends tied together, and the "bite," to use a sailor's term, immersed in the oil; by this means its contact with the bearing is ensured, and if it should from sediment become in the least dry, it adheres to the shaft, and is dragged around to present a new surface.



Arranged with Two Cylin.—Has self-contained grinding devices for sharpening

Every advantage of any other plan is attained in this, and a greater security ensured.

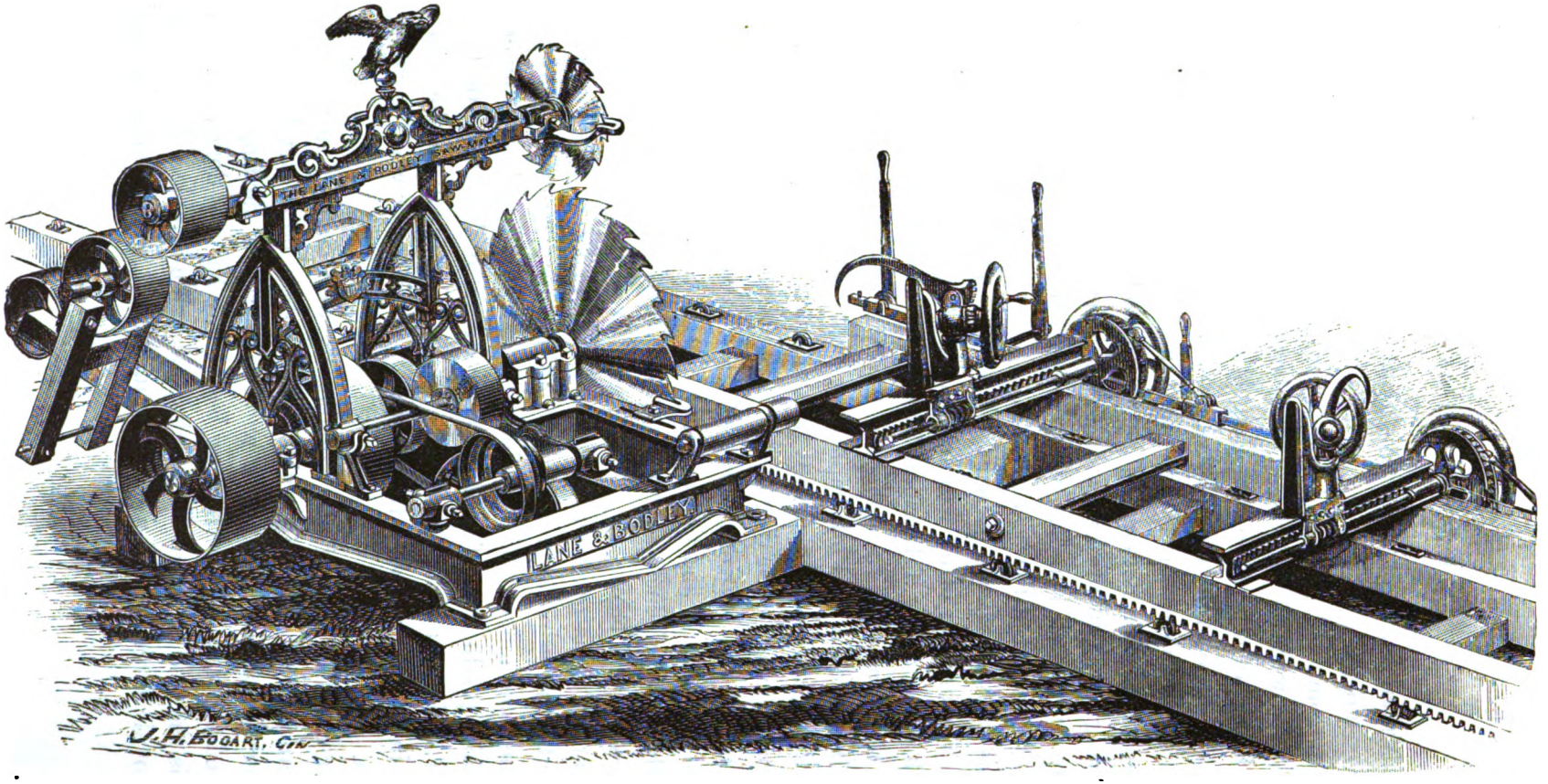
With common wicks, and the lower grades of lubricating oils, there is, even when every precaution is used, great danger in relying for any length of time upon self-oiling bearings.

There is also in the use of this class of bearings with oil-chambers the very serious objection of using the same oil over repeatedly, until its lubricating power is gone, either by the collection of sediment or the wearing out of its properties; in fact this feature unfits it for application to high-speed spindles, which often can only be kept cool by the use of fresh oil of the best quality.

It is mentioned, too, by some of our best mechanical engineers, that a given amount of oil will lubricate a bearing for a longer time, and with better effect, if distributed regularly upon it, allowed to run off, and then wasted. In support of this we can cite the practice of Wm. Sellers and Co., of Philadelphia, who have given the subject a full consideration, and who generally recommend for their line-shafting the thermatic oiler, consisting of a transparent bulb, or oil-cell, placed on the top of the bearing; being of glass it continually shows how much oil it contains, and the certainty of action is certainly as great as in the case of enclosed and inaccessible oil-cells formed in the casting, or around bearings. In the mention of the practice of Wm. Sellers and Co., as good authority to follow in this matter, we may state that there is perhaps no other engineering firm extant that has given the same amount of attention to line-shafting and its adjuncts. Their daily production of such shafting cannot be less than 100 feet, with its fittings, all of which are peculiar, and will be hereafter noticed in connection with the subject of shafting for wood-working factories.

For the bearings of the spindles of wood-cutting machines a good plan is in all cases to provide a tallow-box, no matter how they are otherwise oiled. The tallow will in the case of heating as a rule be melted and run into the bearing before any harm is done; besides, tallow is the best lubricant for bearings that give trouble. Aside from this, provide large free oil-ways, communicating with grooves in the

PLATE XXIII.



CIRCULAR SAW MILL, WITH TOP SAW.

For Forest Use.—For timber to 48 inches diameter, 30 feet long.

LANE and BODLEY, Cincinnati, U. S. A.

bearing cut *exactly parallel with the shaft.* Helical grooves cut in bearings, to carry the oil from the centre to the ends, or *vice versâ*, are not so good; they tend continually to rid the bearing of oil, and their action is frequently not understood by those who operate the machines. Such grooves, too, should not, as commonly made, be triangular, with their base at the shaft, but should be rectangular in section, so as to have the largest amount of section without taking so much from the surface of the bearing; besides, when made in this form they collect more readily the sediment that accumulates in the bearing. For high speeds such grooves should be cleaned as often as once a week in all cases where the bearing is in constant use.

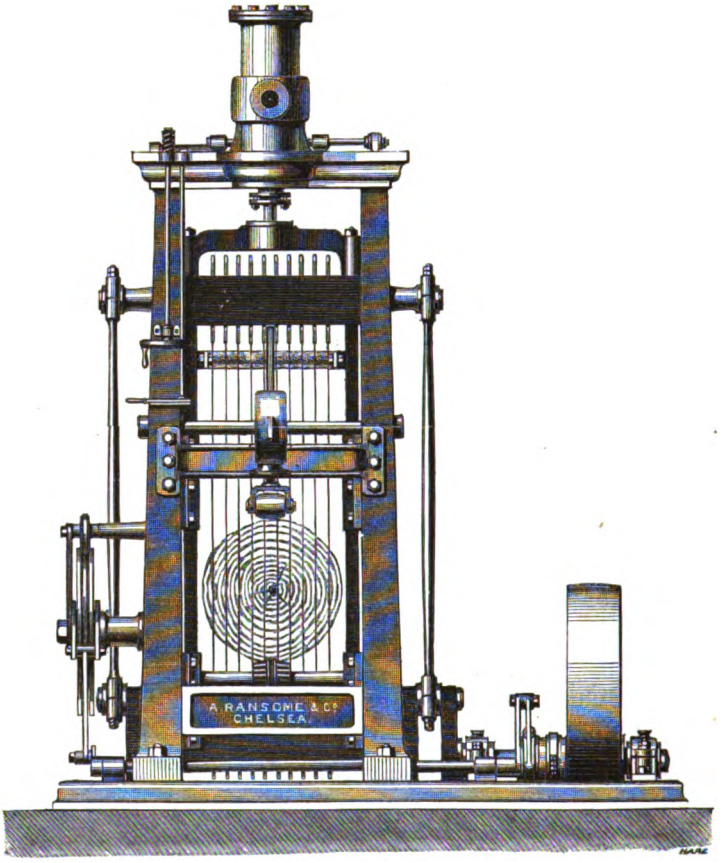
LINE-SHAFTING.

Shafting for operating wood machines, like nearly everything else pertaining to them, requires to be special in many regards. The speed of the main lines should, for the most economic and simple arrangement, never be less than three hundred revolutions a minute, which is alone a sufficient distinction from ordinary cases to warrant the statement of its being special. An average speed for the countershafts, or first movers, in wood machines is about three times as much, which gives as a rule a proportion of three to one between the pulleys of the line and the countershafting.

Shafting of from $2\frac{1}{2}$ to $3\frac{1}{2}$ inches diameter running at this speed must be true as to turning and straightness; the pulleys must be carefully balanced, and the bearings long and pivoted, with careful provision for lubrication. There is as a rule more belting to be carried on the shafting of wood-working manufactories than in those of other kinds. This is directly as the amount of power employed, with enough added to make up for the dry state in which the belting has to operate. The usual large amount of belting makes a great strain upon the bearings, especially as it must be tightly stretched to obtain

PLATE XXIV.

(TRUE ELEVATION.)



DIRECT-ACTING STEAM-GANG SAW MILL.

For Timber Cutting. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

SAW SPINDLE.

To Mount on Wood Framing.

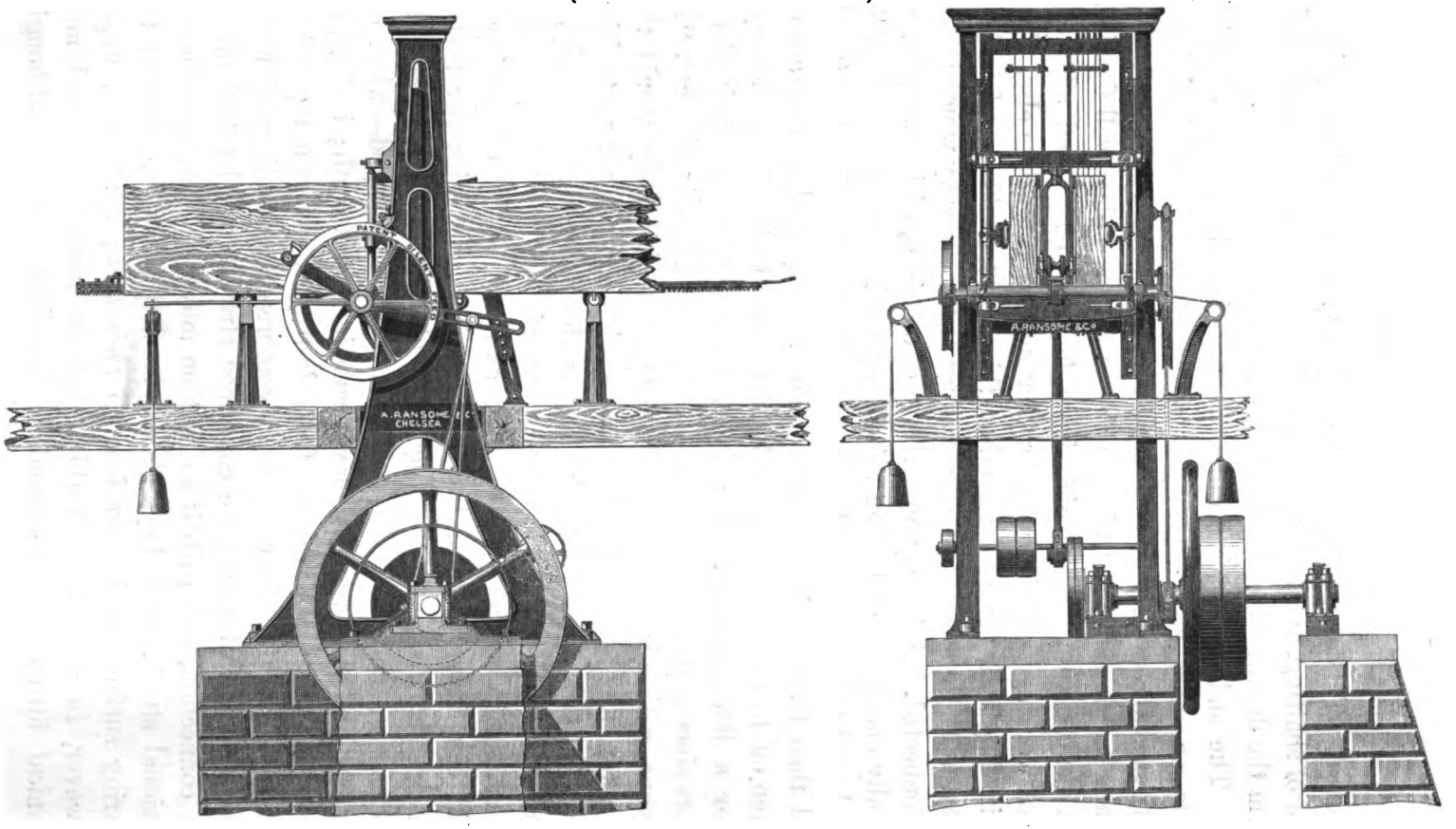
ALLEN RANSOME & Co., London, England.

traction. Taken upon the whole a factory of this kind requires the best of shafting, and the greatest care in its operation, or else the delays from the derangement will be frequent and long.

The sudden starting of heavy machines by means of shifting belts, or, more especially, by means of slack belts with tightening pulleys, subjects the shafting and its connections to severe torsional strain, and is very apt to loosen the couplings unless well fitted or of the compression kind, which is in fact the only kind adapted to wood-working factories, and, for that matter, anywhere else. There is in England, perhaps, no other thing that could so safely be set down as an "anomaly" in engineering as the plans by which shafting is connected. A long clumsy sleeve of cast iron, with a wedge-key, is usually employed, and when this is not used heavy flanged couplings are keyed to the ends of the shafts, each one being fitted to its place and then faced off in the lathe. The mystery is, how they are ever taken off to put on pulleys, or how they can be fitted so as to stay on after a few removals. In a letter written to 'Engineering' some years since a Manchester contributor remarked facetiously that, "how anyone with his head properly coupled to his body would think of using any but a Sellers' compression coupling was to him a mystery." We have no desire to put the matter thus strongly, but must say that, considering the inconvenience of removal, the want of system in manufacture, as well as the difficulty of keeping the solid couplings tight on line-shafting, it is very singular that the present plan has not been long since abandoned. A coupling that is drove on and wedged—we will not term it keyed—when once removed and then replaced never runs in perfect truth; besides, at a second or third removal the fit is destroyed, unless a tapered one. For wood-working factories good compression couplings should be used, such as will ensure the continued strength of the shaft through the connection, and grip it so that no movement can take place by torsional strain. The keys should be deep; that is, wide on their bearing surfaces, and *never bear on their back*; a rule that applies, however, in all cases. Nothing but the most clumsy and unmechanical fitting ever confounds a key with a wedge, although a

PLATE XXV.

(TRUE ELEVATIONS.)



DOUBLE SLITTING MILL.

For Slitting Flitches into Boards.—Has intermittent roller feed; two gangs of saws.

ALLEN RANSOME & Co., London, England.

recent book treats it as a wedge, with its most important function to be that of splitting the hub or straining it out of truth, the author does not say which.

Pulleys for line-shafting running at high speed should be light and true; weight is to be avoided on account of torsional strain from momentum, and perfect truth is needed to prevent a kind of oscillation, or vibration, that takes place when the strain of belts is not uniform; in short, the shafting about a wood-working establishment should be first-class in all respects; whatever contributes to its good performance at slow speeds becomes doubly important at high ones.

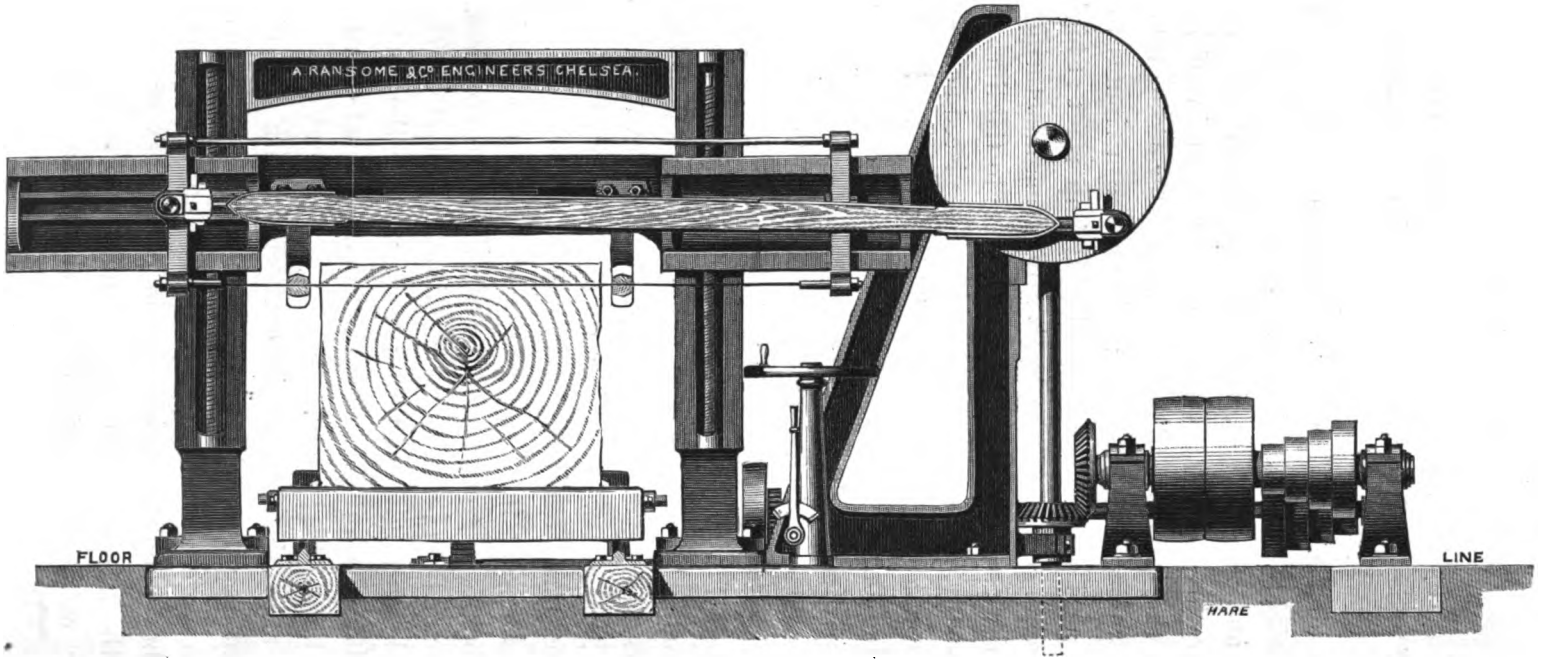
The general course of the lumber in a manufacturing establishment is lengthwise the building and transverse to the lines of shafting, which are usually, in the smaller class of mills, placed across the room, or in its narrow length, at intervals. This arrangement not only contributes to the convenience of belting to the machines but admits of stopping a portion of the shafting for repairs while the rest can be used. Transverse, or timber, planers require in America for railway-carriage work a length of from 75 to 100 feet of framing, while roller-feeding, or board, machines need from 50 to 80 feet; this necessitates an arrangement of the shafts across any but a very wide building.

Hangers, or supports for overhead shafting, have undergone more modification, and are produced in a greater variety of forms and plans of adjustment, than almost any other detail in machinery. That taste as to design has been the main reason of this is evident in the fact that a number of engineers would, with the same premises, generate about the same thing. A greater uniformity of strength, if not of design, would certainly exist if it were not for the contingency of winding belts, with other accidents, that can be set down under the general head accidental strain.

This matter was noticed in connection with the diameter of shafting, and applies to hangers as well. In wood-working mills and factories there is less danger from winding belts because of their being dry, but when such accidents do occur they are more serious because of the greater width and strength of the belts. Hence all hangers for wood-cutting machinery should have extra strength,

PLATE XXVI.

(TRUE ELEVATION.)



HORIZONTAL RECIPROCATING-SAW MILL.

With Carriage Feed.—Intended for mahogany and other valuable hard wood. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

especially for overhead shafts, and be, with their supports and bolts, strong enough to part or tear the belting without other danger. To determine the cross-section of a pendent support that will do this is not an easy matter, but experience and judgment will generally suggest proportions that are strong enough. A "cored section" is, without doubt, the strongest one for hangers, which forms no exception to the rule for columns or beams, of disposing the material as far as possible away from the neutral axis and on the periphery.

The cored hangers shown with some of the machines in the plates have proved very strong, even when very light. Those seen with the saw-bench of the Atlantic Works have 13 inches drop, weigh 17 lbs. each, and cannot be broken with a 5-inch single belt of ordinary manufacture.

Pulleys for wood-cutting machines should be strong, and safe from the danger of centrifugal strain due to high speed. Cast-iron pulleys with proper proportions, and made of close strong metal, are comparatively safe with their rims moving 5000 feet a minute—a limit, however, which should not be exceeded. Such pulleys are, as a rule, turned both on the outside and inside of the rim, which should be rather heavier than usual.

We give a formula from the Industrial Works, W. B. Bement and Son, of Philadelphia, which furnishes proportions that are well adapted for high-speed pulleys:—

Diameter of pulley D.

" " " Pattern $= D + \left(\frac{D \times 1\frac{1}{4} + 10}{100}\right)$

Face F " " " $= F + \left(\frac{D + F}{100}\right)$

Edge thickness of rim E $= \left(\frac{D}{2} + 8\right)$ an increasing progression, A $= 8\frac{1}{2}$, R $= \frac{1}{2}$, N $= D$.

Centre " " " $C = \cdot 03\, F + E$.

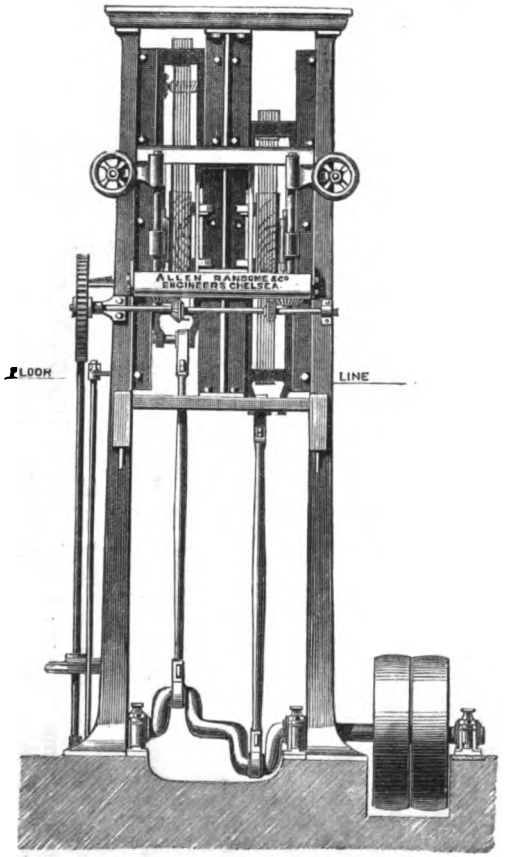
Number of arms N; when $D > 12$, $N = 5$; $D > 30$, $N = 6$.

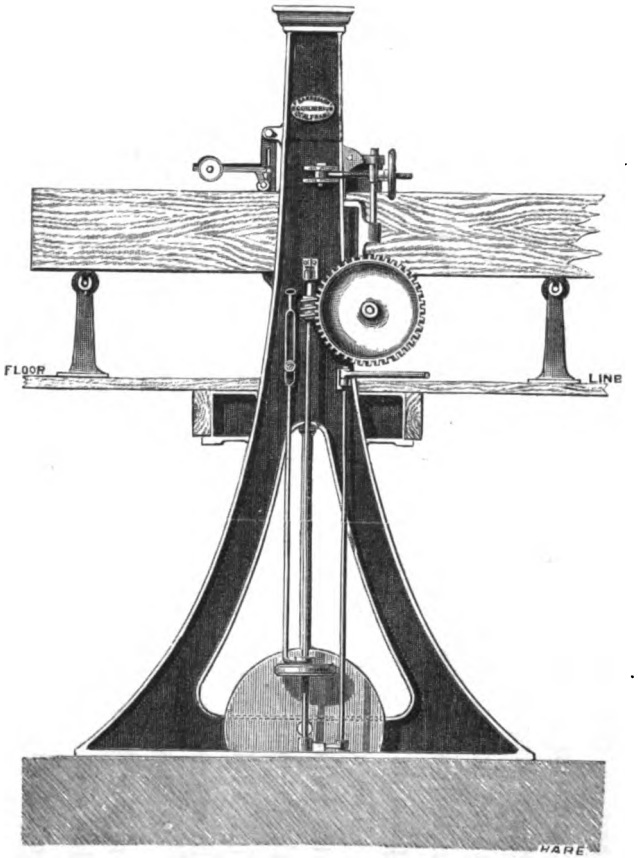
Breadth of arm at rim $B = \frac{\sqrt{D \times \cdot 6\, F + 10}}{N}$, increasing to hub 1" in 16".

Thickness of arm $T = \frac{B}{2}$, parallel from rim to hub.

PLATE XXVII.

(TRUE ELEVATIONS.)





SLITTING MILL FOR DEALS.

With two gangs of saws; feed continuous. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

HUBS.

Parallelogram of web P = $\sqrt[3]{D+F}$, shown in Fig.

Web of hub W = P + T, as shown in Fig.

Shaft to be used S.

End diameter of hub H = $\frac{\sqrt[3]{D+F}}{4\cdot5}$ + S, or $\frac{P}{4\cdot5}$ + S, increasing 1″ in 16″ to web.

Metal thickness of hub M = $\frac{P}{9}$ when set-screw bosses are used; for *s p* line add $\frac{1}{2}$ to M.

Versed sine of facial curvature = $\frac{F}{64}$ for high faces.

RECIPROCATING MOTION IN WOOD-WORKING MACHINES.

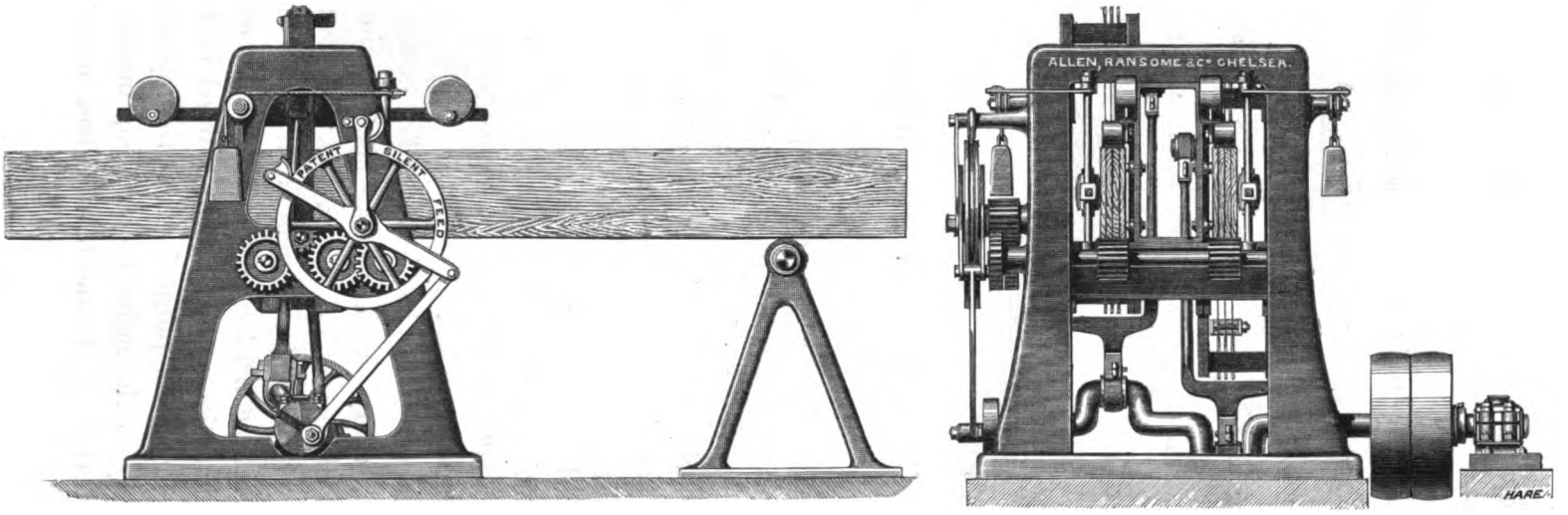
Before entering into any remarks upon sawing machinery we will devote some attention to reciprocating machines in general.

That reciprocating motion is very imperfectly understood is a fact that no one with an experience among the makers of machines will dispute. There is, of course, nothing involved in it that is not fully comprehended in the known laws of physical science, and it is, in that sense, well understood; our meaning is, that such knowledge has not been sufficiently elucidated in text-books, or has failed to be appreciated and understood by those who are practically concerned in its application to construction.

Science in its researches has left but few nooks in the industrial arts unexplored; every detail of shop manipulation, every conceivable application of mechanical forces, has, with but few exceptions, passed through the ordeal of scientific criticism and investigation. Even the most simple matters have become the subject of abstruse mathematical calculation, and are demonstrated in formulas that are a hundredfold more complicated than the operations themselves. This zeal to apply mathematics to our shop manipulation, or rather to all matters pertaining to mechanics, has, no doubt, in a large

PLATE XXVIII.

(TRUE ELEVATIONS.)



RE-SAWING, OR SLITTING MILL.

With Two independent Gangs of Saws for Sawing Deals into Boards.—Has intermittent roller feed. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

measure, to be imputed to a recent realization of the fact that they are intimately connected. But now that experience has proved that the mechanics who rely upon scientific data, and who follow the principles of construction as laid down from the deductions of scientific men, are the only ones to succeed, it has not only awakened an interest but a pride in the amount of such knowledge possessed in our shops. This zeal to study theoretical mechanics is sufficiently attested in the number of polytechnic and other scientific institutions of learning of this kind that have recently sprung up.

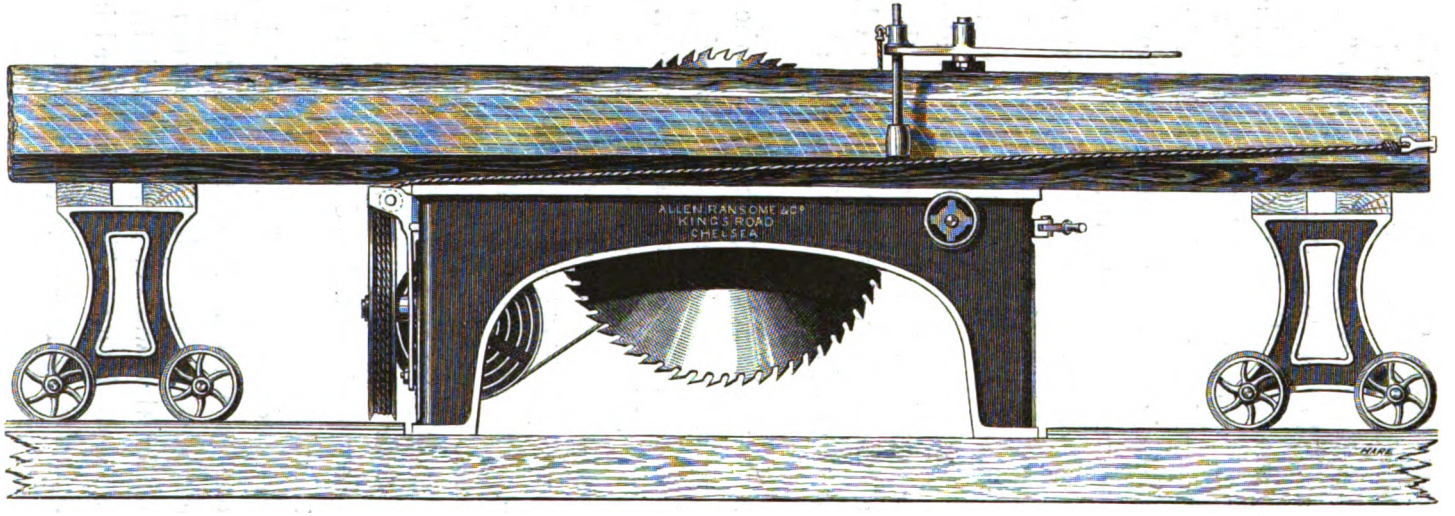
The discovery of the mechanical equivalent of heat has done much to restore confidence in the theoretical laws of mechanics. Without this philosophy a link in the chain was wanting; there was a stopping point to theoretical deductions about forces; much that could not be explained in a manner sufficiently rational to gain the confidence of mechanics when they had been educated to regard *book learning* on the subject as pernicious, and almost unfitting one for the shop.

Everything in mechanics, as in nature, is the subject of fixed laws. To interpret these laws is the business of science, and to spread before the mechanic a chart on which he can rely. An apprentice who enters the shop with the impression that the business he is about to learn is something mysterious, and that he is to grapple about in the dark, stumbling upon his ideas solely from experiment, will never master his trade. There must be a fixed confidence in constant results. He must, to succeed, know that all he is to learn is governed by fixed and unalterable principles; that there is a tangible something which he can in time master; and that he *can* LEARN HIS TRADE, a proposition that would be untenable unless his business could be considered as a demonstrated art.

The subject of counterbalancing, as applied to reciprocating movement, is one of these *nooks* that seems to have escaped the scientific research so lavishly expended on matters of much less importance. A reason for this was set forth in the introduction to these articles, where wood-working machines were placed in the same category. Aside from the reciprocating parts of the steam-engine, the

PLATE XXIX.

(TRUE SIDE ELEVATION.)



SAWING MACHINE.

For Slitting Straight Lines.—With power feed and auxiliary carriages. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

question of such counterbalancing is confined mainly to wood tools. For although cutting operations on other material are much the same, it is only in wood cutting that a high velocity is needed and a corresponding necessity for counterbalancing exists.

Counterbalances on saw-mills and scroll-saws are themes as old as our country. Old millwrights who built our "log-sawing" mills of rude and imperfect construction, in the absence of anything but their personal judgment and experience to guide them, had nothing of more interest to argue or differ about than counterbalances.

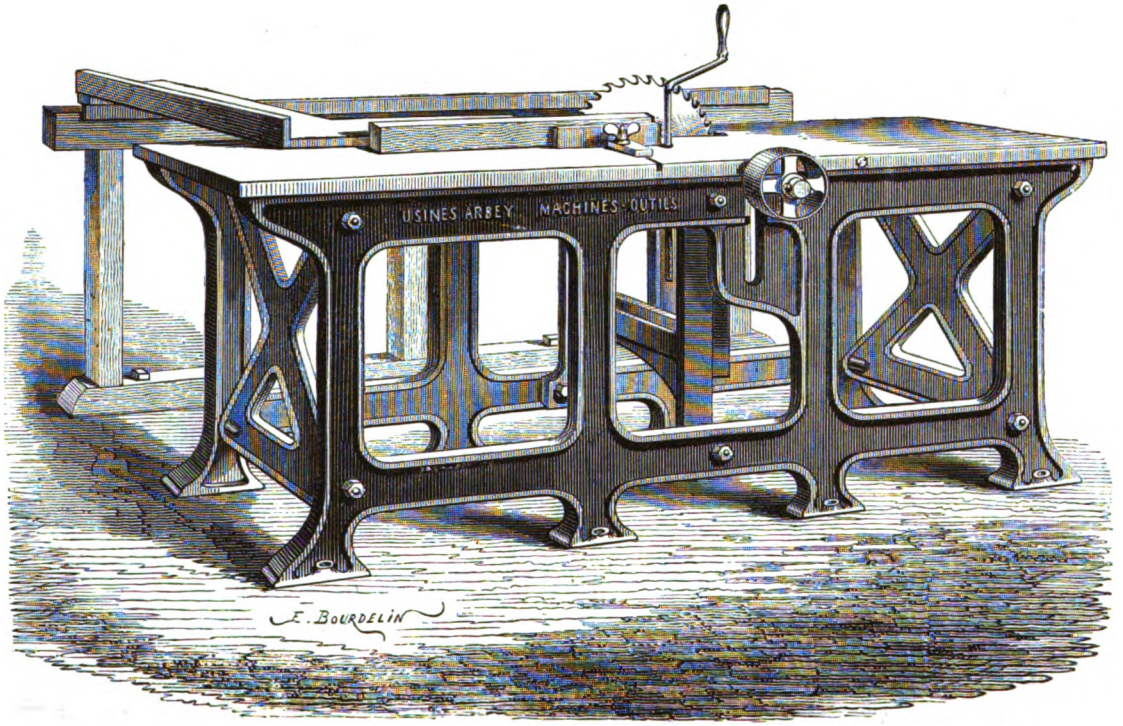
A scientific journal has recently published numerous communications on the subject of such counterbalances, containing a diversity of opinions, which prove conclusively that there are no scientific data to determine the matter, at least in any form that is available to mechanics generally, and justify the assumption that one important feature in construction has been overlooked in our voluminous textbooks.

A patent granted to Captain John Ericsson during his 'Monitor' career, for counterbalancing the reciprocating parts of machines, was about the first published matter that directed attention to the true theory of counterbalances. It was comprehensive, and showed the acquaintance of this celebrated engineer with the matter. It related in substance to counterweighting the reciprocating parts of machines by means of balances of equal weight with the parts, having a coincident movement in a reverse direction; or of weights greater or less, with a proportionate range of movement, inverse, of course. These may not be the precise words of the patent, which is quoted from memory, but are the claims in substance.

In 1866, about the same time or about the same year of the Ericsson patent, Mr. James R. Maxwell, a mechanical engineer of Cincinnati, Ohio, designed an eccentric turning lathe on the same principle, having a compound face plate or sliding frame, so arranged that the amount of ponderable weight was at all times the same on every side of the axis, independent of the piece being turned. Eccentric lathes were used for turning oval picture-frames and similar work, and were among the most difficult of all machines to "hold still," so

PLATE XXX.

(PERSPECTIVE ELEVATION.)



SAWING MACHINE.

For Slitting, Cross Cutting, Grooving, and Rebating.—**Spindle has vertical adjustment.**

F. ARBEY, Paris, France.

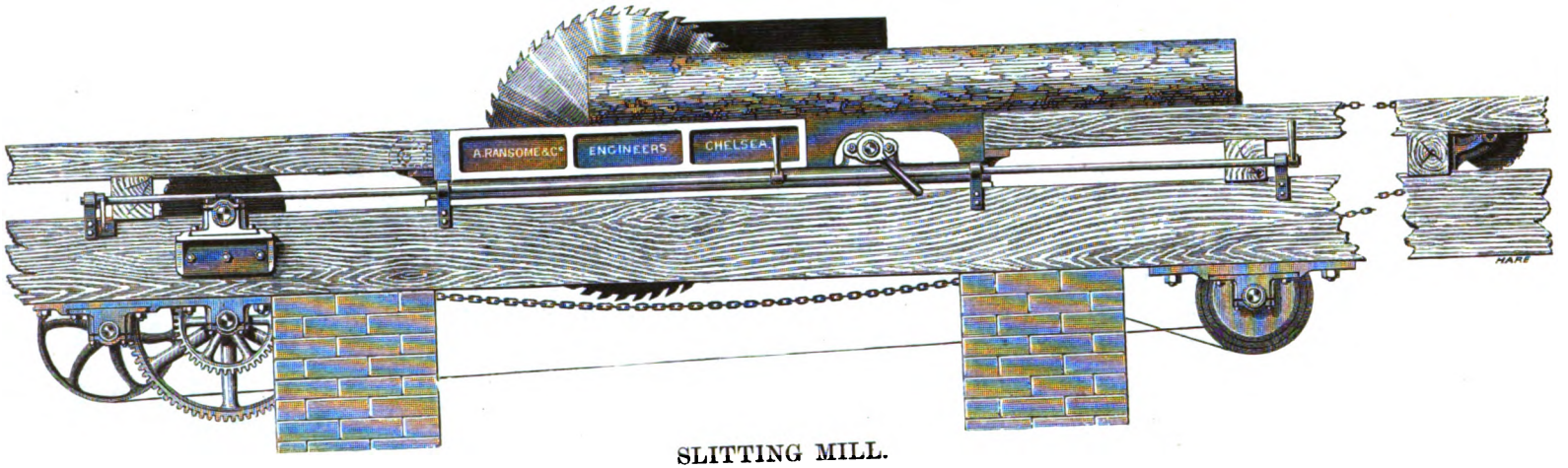
much so that in some instances it has been found necessary to build a solid wall of masonry over them, so that the vibration might fall in its plane and be resisted.

With Mr. Maxwell's improvement these machines are operated on the floor like a saw, or moulding machine, and cause no more jar or vibration than other machines with only rotary action. A popular idea exists that the frame, or other reciprocating parts of saw-mills, gig-saws, floating machines, &c., can be balanced by putting an equal weight or a balancing weight on the opposite side of the crank-wheel; a plausible and indeed true proposition, so far as vertical movement is concerned, but under ordinary conditions it is simply changing the evil and throwing the strain or vibration in a new direction, in which it is more difficult to meet it. Such balances are often added as a matter of convenience, so that the machinery will stop in any position, and for such objects are well; but to prevent vibration, the policy of applying counterbalances to the crank is to be governed by the nature of the attachments and foundations of the machinery, whether such vibration can be best visited in a vertical or a horizontal plane. In short, there is no possibility of balancing in any degree the reciprocating parts of machines by placing weights opposite to the crank; or, to state it in a more general way, reciprocating weight cannot be balanced by rotary weight.

By adding such counterweights, as before said, the vibrating strain can be changed from a vertical to a horizontal direction, or can be divided between the two, which is, upon the whole, the best that can be attained in practice; that is, to add to the crank-wheel about *one-half* the weight needed to balance the reciprocating parts. This, of course, would be a rule only when the conditions of erecting were not known to the maker of the machines, and in such machines as might either be set on earth foundations or floors, for if this matter is known, there is no trouble in determining the best arrangement for balances. Earth foundations and floors present nearly opposite conditions in the way of resisting vibration. On the earth, vertical resistance is easily attained; on a floor, the strength or resisting power is horizontal; and when the reciprocating parts of machines

PLATE XXXI.

(TRUE SIDE ELEVATION.)



SLITTING MILL.

With endless chain feed. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

can be brought anywhere near the plane of a floor, it becomes one of the most solid "abutments" to absorb jar or vibration.

The effect of a counterweight is to change the vibration in sawing machinery from a vertical to a horizontal direction; that is to say, any counterbalance applied on the crank-wheel is itself equally out of balance with the parts which it is to correct, *when considered on a line transverse to the rectilinear motion of the saw.* It is quite impossible without diagrams to give a comprehensive explanation of this counterweighting of saws, which must be left to some more scientific treatise; yet the general principle involved can be stated as follows, and will furnish a problem for those who, from interest or curiosity, choose to further elucidate it.

First. The vibratory effect of the reciprocating parts of sawing machinery is on a vertical line, directly as the aggregated weight of the saw-frame and its connections to the crank-pin.

Second. The effect or tendency to vibration on a horizontal plane, or transverse to the line of the rectilinear movement, is as *one-half* the weight of the connecting rod, less so much as has its centre of gravity on the crank-pin when in a horizontal position.

Third. The crank-pin, with all permanent attachments to the crank-wheel, and so much of the connecting rod as has its centre of gravity on the crank-pin, become, as it were, a constituent part of the crank-wheel, and admit of perfect counterweighting.

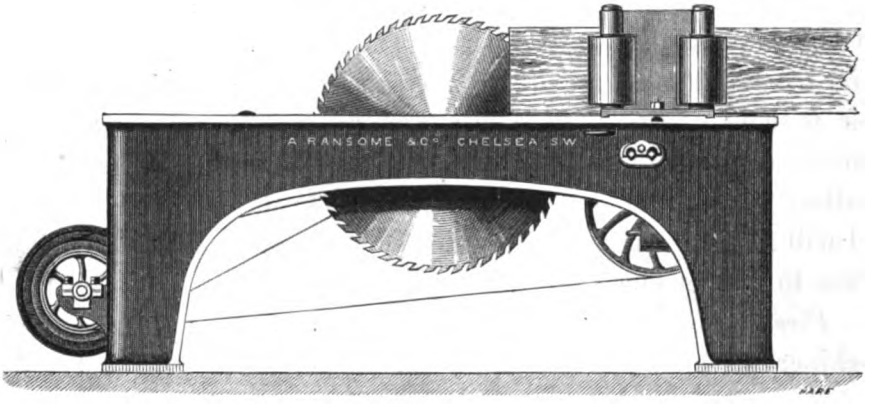
In regard to the second proposition, the element of movement is left out, which on horizontal planes diminishes from the crank-pin upward, yet the proposition is approximately correct.

In the third proposition the connecting rod is supposed to be placed in a horizontal position, then divided at a point that would leave an equal or balanced amount of its weight on either side of the crank-pin. This part of the connecting rod is then to be considered as a part of the wheel, or, in other words, as having rotary motion and admitting of a balance.

These deductions are the result of the writer's observation in a number of practical experiments in balancing reciprocating machines making from *twelve* to *eighteen hundred* revolutions a minute, and

PLATE XXXII.

(TRUE SIDE ELEVATION.)

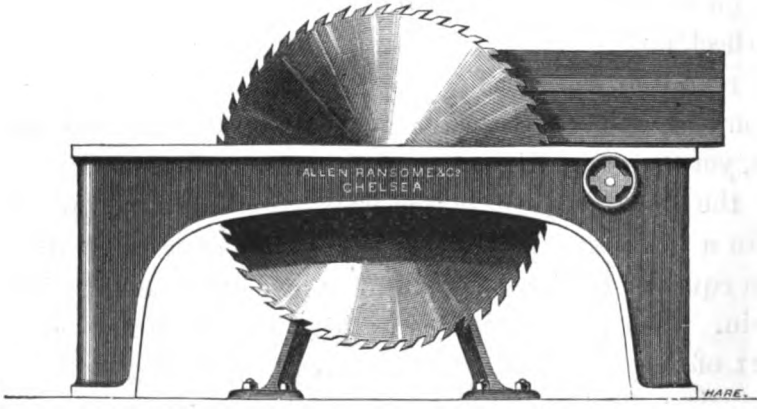


SLITTING MACHINE.

For Deals and Battens.—Has power feed, with geared roller. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

(TRUE ELEVATION.)



PLAIN SAWING MACHINE.

For Slitting. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

while they are not scientifically stated, will no doubt to the practical engineer and mechanic be found to contain some useful suggestions in this troublesome question of how and when to counterweight the reciprocating parts of machines.

ROTARY BALANCING.

There is in the workshop no operation connected with the construction of wood-cutting machines that needs more careful attention, nor one that has more to do with their perfect performance, than the "balancing" of all their parts.

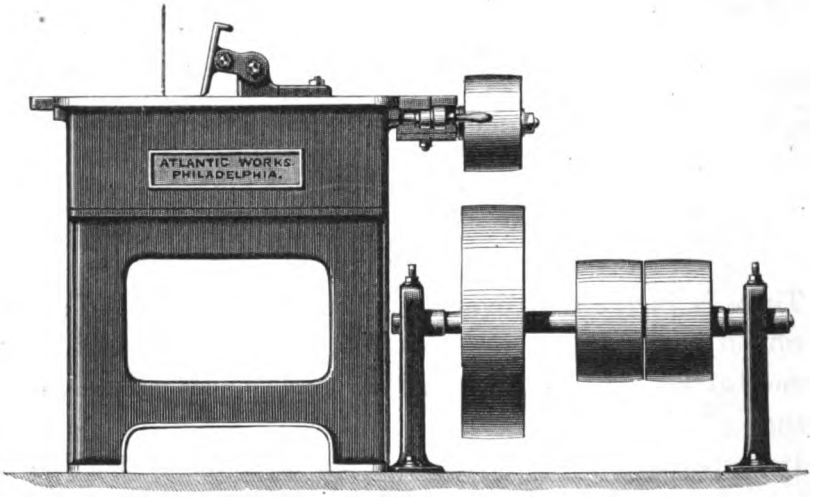
Its importance can be realized when we estimate that the necessity for balancing, or the effects of imperfect balancing, is directly as the speed at which the parts run, and then compare the relative speed of machines of this class with others.

If to this estimate we again add the very sensitive nature of the work, that the least jar or vibration communicates its effect at once to the work, where it appears in what might be termed an exaggerated form, it is easy to see the care that is needed in balancing, especially in the cutter heads and spindles.

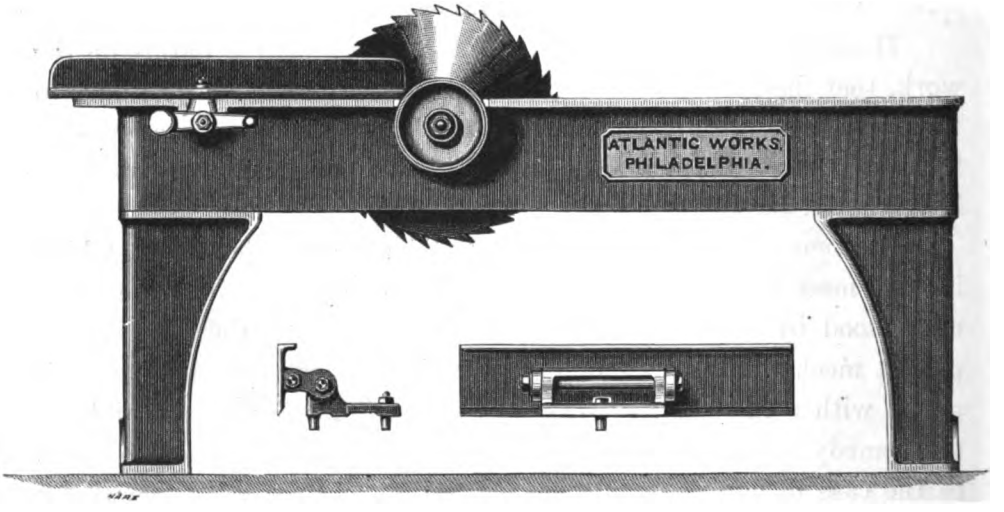
Balancing, although generally considered a simple matter, which it is in most cases, in this connection is not only too intricate to be understood by ordinary workmen, but unfortunately there is no very perfect mechanical means for determining it, if we except the experiments with a finished machine, which only indicate the fault and not the remedy. When the weight is disposed nearly in one plane, as in the case of a disk or wheel, or a pulley, it is easy to balance by "rolling" on level straight edges; but when the weight is disposed throughout some length around the axis, this plan becomes quite uncertain. To illustrate, we will suppose a shaft two feet long to have a pulley on each end, one of which is eight ounces out of balance; by placing this shaft on the balancing bars and adding eight ounces

PLATE XXXIII.

(TRUE ELEVATIONS.)



END VIEW.



SIDE VIEW.

HAND-FEED SLITTING SAW.

For Straight and Bevel Lines. *Scale*—$\frac{1}{16}$th, $\frac{3}{4}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

to the other pulley, an apparent balance is made, while the fact is, that the evil has been doubled, instead of corrected.

The axis then would pass through the two pulleys, in a direction diagonal to the centre of gravity, and the effect of balance in the second pulley be just the same at its end of the shaft as the want of balance in the first. In the case of pulleys or other fittings that can be separately balanced, of course no case just like this need arise; yet there are many cases in which this plan is impossible, as in the case of planing cylinders or in castings of some length when the want of homogeneity or imperfections makes balancing necessary.

A plan adopted some years since in America for balancing the cylinders of threshing machines seems to be the best one yet devised for such cases. The operation is as follows:—The bearings or projecting ends of the shaft are turned very true and smooth, leaving a light cut to be afterwards taken off in finishing.

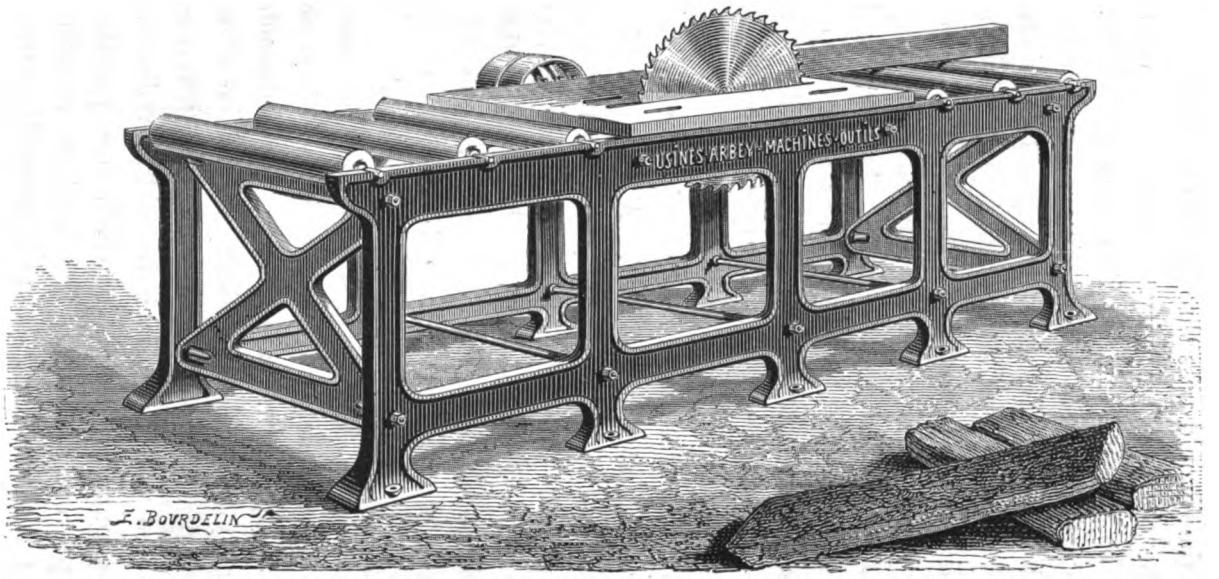
The cylinder is then mounted on points or in a common lathe, and started running at a high speed. A nice point is then brought in contact with the finished shaft at each end, which will be scratched at the "high point;" indicating the least strain or vibration from a want of balance, and the position of the fault in the cylinder, by the relative degree with which each end is affected by it. The amount of the counterbalance has to be determined by experiment, which, after a time, can, by usage, be approximately known from the influence on the shaft. This plan, it is claimed, has been entirely successful, and in want of any further knowledge it is presented here as one that could be applied in analogous cases to wood-machine cylinders.

For ordinary use balancing ways should be of steel, fixed to stands so as to adjust vertically at each end with screws. The faces should not exceed one-fourth inch in width, unless a very heavy weight is to be put upon them, in which case parallel bars can be interposed to prevent abrasion. The bearings, or other part of the shaft in contact with the bars, should be carefully turned—should be as perfect as a bearing—for the least irregularity prevents the sensitiveness of the operation, which at best is not a perfect one.

It is difficult to give information in a matter that depends so

PLATE XXXIV.

(PERSPECTIVE ELEVATION.)



PLAIN SAWING MACHINE.

For Slitting Boards and Planks.—Has friction rollers to facilitate the feeding of the piece.

F. ARBEY, Paris, France.

much upon judgment and experience as balancing; and these remarks are introduced more with a view of urging care and nicety than that of furnishing rules of any practical value not already familiar to mechanics.

SAWS AND SAWING MACHINERY.

The saw, as a device for reducing and dividing wood, can, next to the axe, lay claim to an antiquity beyond that of any other known implement for wood cutting. The oldest works relating to mechanics have always the reciprocating saw, in its various modifications, illustrated and described. In fact there seems to be no clue to its origin, unless it exists in the records of Eastern civilization.

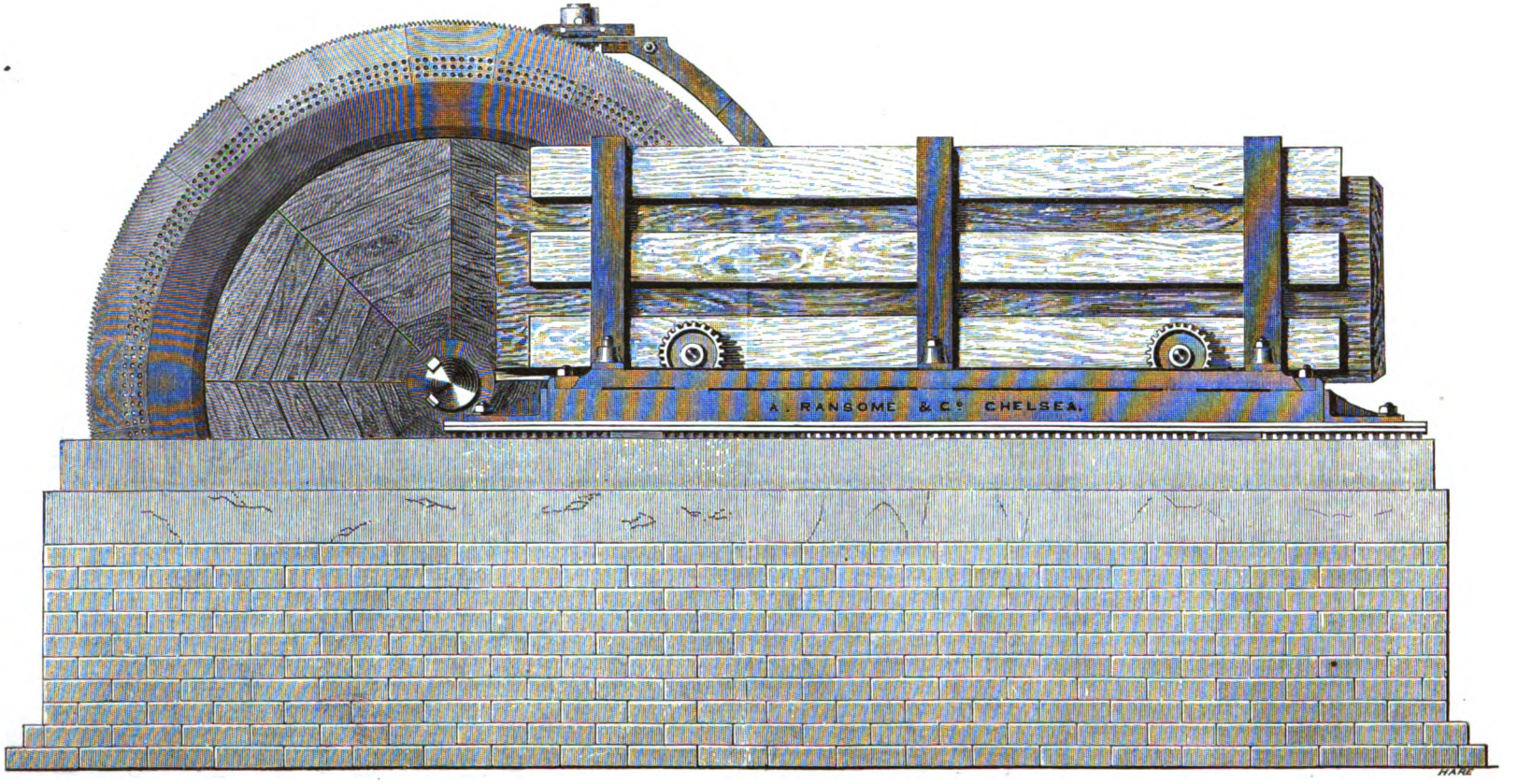
The antiquity of saws is to be accounted for in the fact of their being a simple thing, considered as a mechanical expedient, and in the necessity of having them, to carry on the simplest operations in wood work. Necessity has, as expressed in the old adage, "been the mother of many useful inventions," and a serrated plate of metal to divide wood, or other material, without destroying any considerable part, must have become very early indeed a necessity.

That saws were so invented is in a measure proved by the fact, that just as soon as the necessity was supplied, invention stopped, and down through ages the reciprocating saw was used without the idea of a revolving plate, with a continuous action, having been entertained.

It would seem that the transition from a parallel or intermittent action to a rotary or continuous one was a matter so simple, and having such obvious advantages for many uses, that it would soon have followed. When we, however, consider that rotary motion is mainly confined to machines, that it involves mechanical agents but little known in early ages, and that economy of time, which constitutes the greatest difference between parallel and rotary motion, was no object, it is perhaps after all a matter of no wonder that we find the circular saw with so recent a history.

PLATE XXXV.

(TRUE ELEVATION.)



VENEER SAWING MILL.

Scale—½ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

Circular saws were first used in Holland, where they seem to have been known during the seventeenth century, a period when the Netherlands had placed themselves in advance of every other country in many branches of mechanic art; and indeed had learned so much, that they have not thought it worth while to add much since.

The circular saw was, however, developed in England and in America: we mention America, for its application to lumber cutting on a large scale was first practised there, and is even now a recent thing, as we will notice under its proper head.

Saws, considered independent of the machinery to operate them, can be divided into four classes: Reciprocating saws, Band saws, Circular saws, and Cylinder or Tubular saws. They will be noticed under these several heads.

It must, however, be borne in mind that we have to deal with machines to operate them rather than with the saws themselves—and it will not be attempted to give any technical information as to their manufacture, further than is directly concerned with their operation.

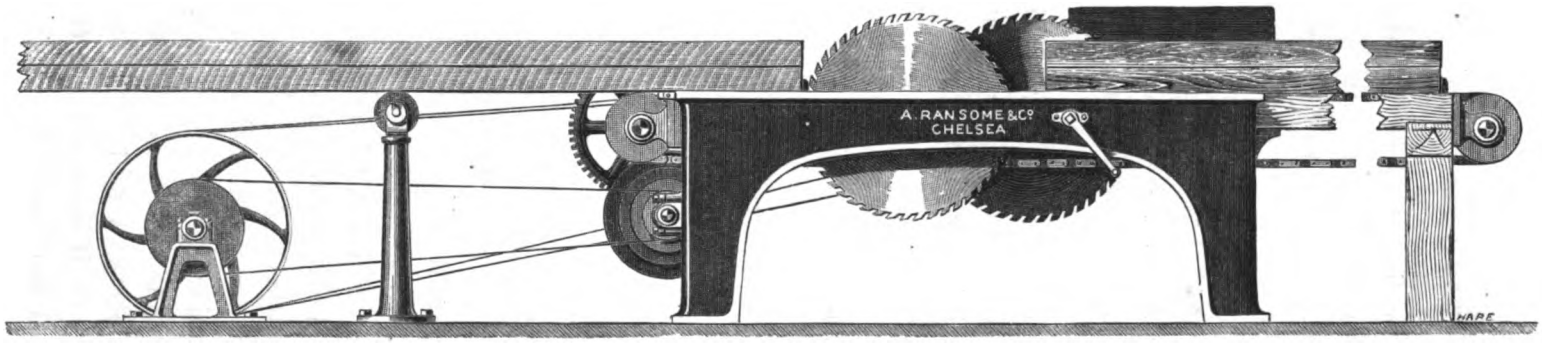
RECIPROCATING SAWS FOR CUTTING TIMBER.

To consider reciprocating saws in the order of their application to wood manufacture, we must begin with the Forest Saw Mill; at least for the American continent, where lumber is sawn in the forest, and is only to a limited extent "re-sawn" at manufacturing establishments. The lumber market of America being the largest in the world, and the conditions under which lumber is manufactured being so varied, we will, in considering reciprocating saws for timber cutting, first confine the remarks to American mills and American practice.

The primitive lumber-saw mill has been in all countries the old style "frame saw" or, as it is sometimes called, "sash saw," with a single blade, mounted in a frame surrounding the log. In the old

PLATE XXXVI.

(TRUE ELEVATION.)



PARALLEL SAWING MACHINE.

For Parallel Lines.—With power feed; used for jointing or edging flitches or boards.

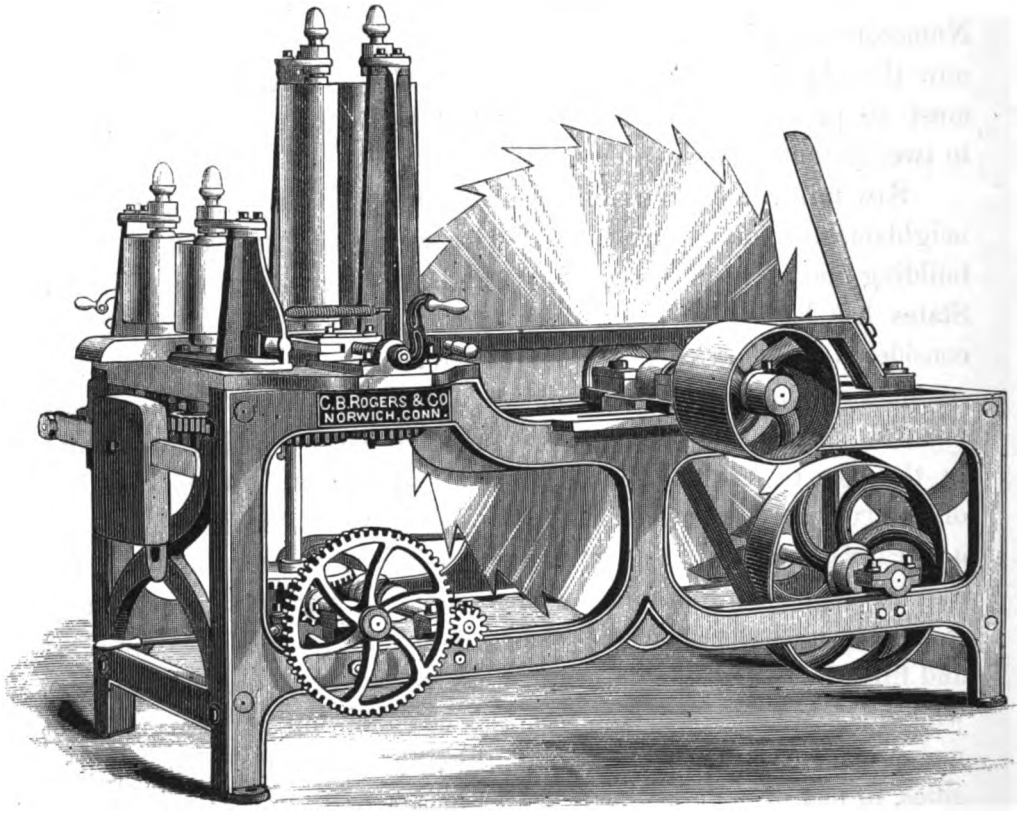
ALLEN RANSOME & Co., London, England.

days of wooden millwrighting, a saw mill was a stereotype sort of thing, consisting of the same parts and arrangement, with the exception of the "water-wheel," which, of course, had to conform to the height of the head. The production of a first-class mill of this type was from two to four thousand superficial feet a day, which, in more modern times, falls far short of what would seem to be a return for the amount of attention and manual labour involved. Numerous improvements and modifications have been produced, until now the old single saw mill is a thing of the past. A set of men must be provided with machinery that will manufacture from ten to twenty thousand feet a day.

Saw mills, like grist mills, were at first for local purposes; every neighbourhood or village needed its saw mill to supply lumber for building and other purposes; but now the lumber traffic of the United States has become a vast interest, and is no longer a matter to be considered in a local way; it is affected by the same conditions that regulate or influence commerce of any kind. To illustrate the extent of manufactures in wood (not lumber cutting), we will mention that in the city of Cincinnati, Ohio, in 1869, *two hundred million* feet of lumber were manufactured into joiner work, furniture, wagons and carriages, &c.; no doubt a small share of the amount was sold and re-shipped without being manufactured, but if there was any it was but a small part of the whole. Cincinnati has but two hundred and fifty thousand inhabitants, and aside from furniture manufacture, which is extensively carried on, the consumption of lumber is not more, in proportion to the population, than that of other Western cities, in fact does not compare with Chicago or Detroit in this regard. With such a lumber consumption as this, as a matter of course, attention was directed to cheaper forest cutting. The best skill and the greatest experience was brought to bear on the improvement of sawing machinery. The gang saw, the muley saw, and circular saw were tried; the first innovation being, of course, the gang mill, which was all very well when the timber could be collected at one place. Gang mills require heavy, strong foundations, and are not in any sense portable, yet for economy in lumber cutting are the best modi-

PLATE XXXVII.

(PERSPECTIVE ELEVATION.)



SLITTING SAW.

For Splitting or Re-sawing Boards or Planks.—With power feed.

C. B. ROGERS, New York, U.S.A.

fication in use. Hence, there became established at St. Anthony, on the Mississippi, the Falls of the St. Croix, in Wisconsin, at Menamonee, and Saginaw, in Michigan, those vast systems of roller gang mills which have no parallel in the world. A circular saw for edging and squaring, with a gang for slitting the stocks at one operation, is the equipment of a modern mill for ordinary lumber. This outfit is, of course, duplicated many times in a large mill. At St. Anthony in Minnesota, there are as many as twelve such mills in a single block.

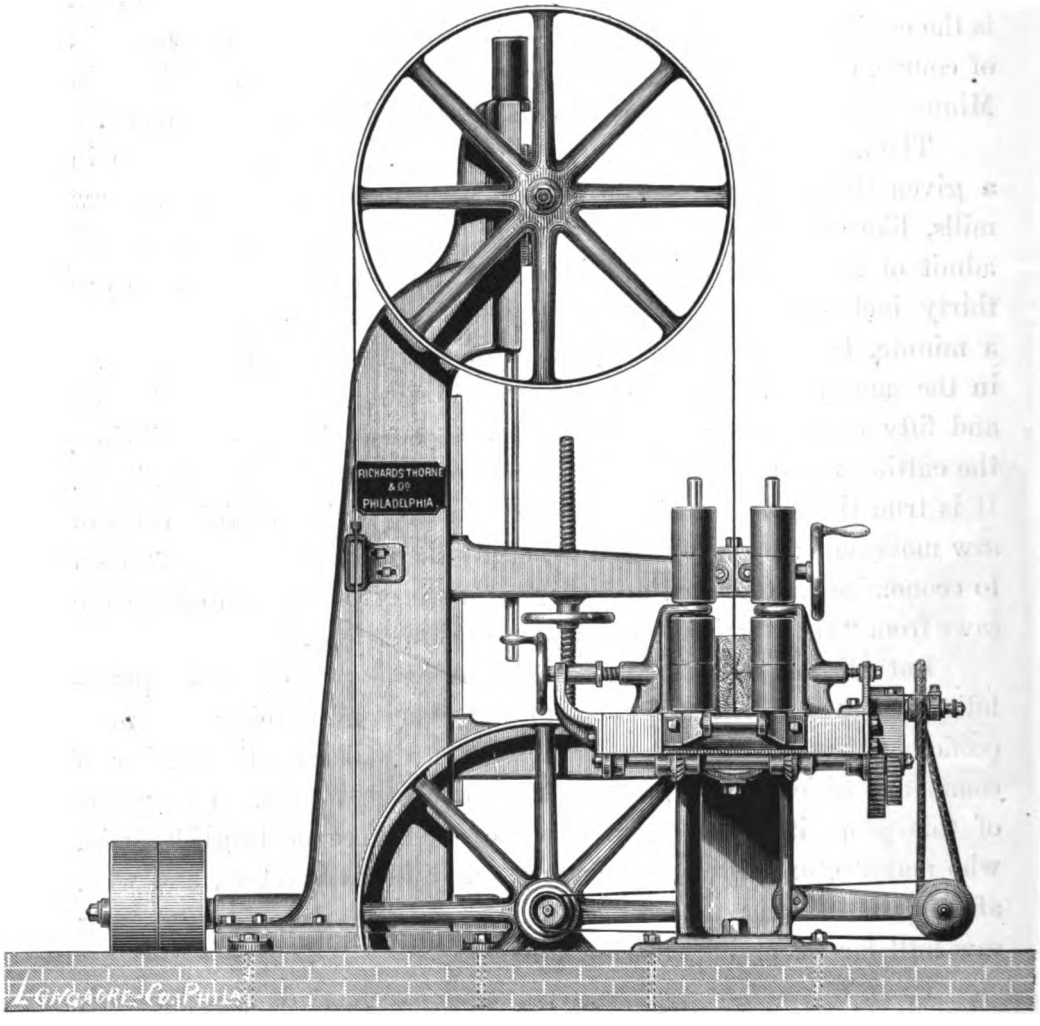
The speed of the teeth, or the number of teeth that operate in a given time, is the exponent of the performance of saws; and saw mills, like other machinery, are governed by mechanical laws which admit of theoretical demonstration. A single reciprocating saw, of thirty inches stroke, making one hundred and eighty revolutions a minute, has a cutting movement of four hundred and fifty feet in the same time. In a gang of twenty saws, making one hundred and fifty revolutions a minute, with a stroke of twenty-four inches, the cutting movement is in the aggregate *six thousand* feet a minute. It is true that gang mills do not cut in proportion to this ratio of saw movement; but the reason is mainly that thinner blades are used to economize in the kerf, and there is more care needed to keep the saws from "running," and consequently slower feed.

But all things considered, and leaving out the idea of portability, there is no question as to the gang mill being the most economical for the manufacture of what we will term the lumber of commerce, which is in America mainly one-inch boards. In support of this proposition we might cite the experience of English firms, who manufacture sawing machinery for different markets, and who, after quite a long experience, make only the reciprocating gang saw mill for general lumbering purposes.

There are, in the plates given, some excellent designs for such mills, of both English and French manufacture. In America, such machinery is built upon a totally different plan. The mill framing is generally of wood, and is built into, and becomes an integral part of the building, or mill house—a plan that has much to recommend it, when the millwrighting skill can be commanded for erecting such

PLATE XXXVIII.

(TRUE ELEVATION.)



BAND-SAW MILL.

For Slitting and Re-sawing.—With power feed. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

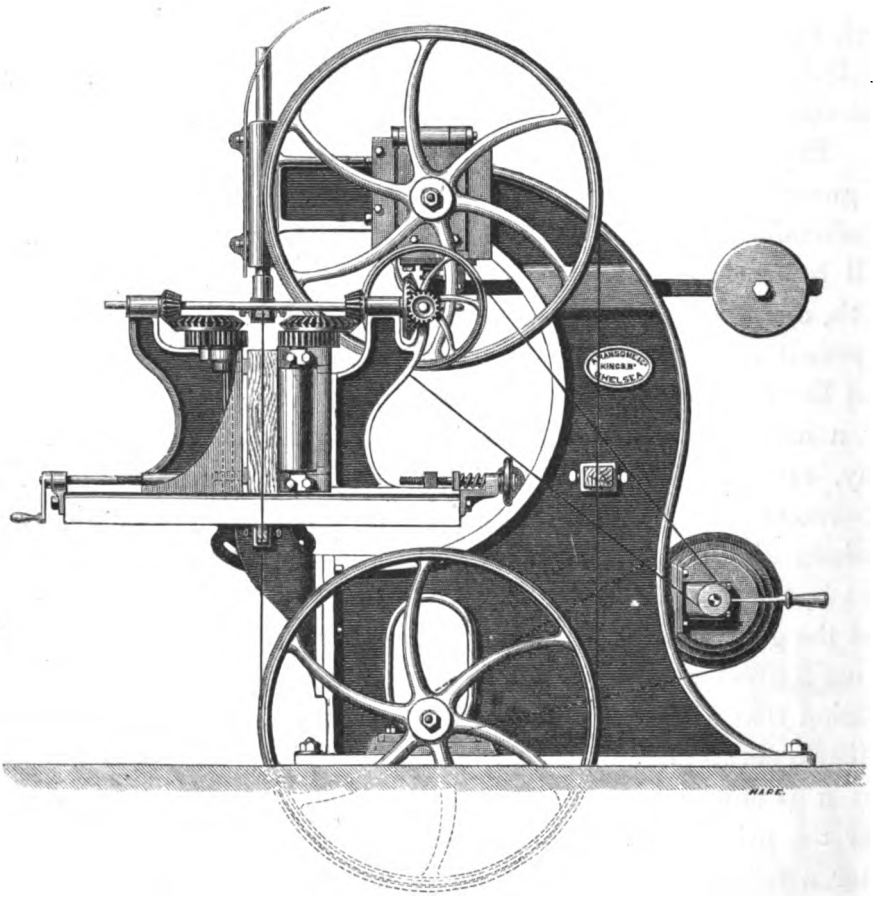
mills; but it is, of course, impracticable in the case of any mill that could be called self-contained, or one that would be adopted as a machine to the general market. It is a local idea, and a good one, considering the conditions that exist in the lumber-sawing districts of America, and the result of the performance of such mills challenges any criticism upon the plans. Even taking into consideration the high rate of wages paid to operatives, and leaving out the question of fuel, there is, perhaps, nowhere in the world where lumber is manufactured so cheaply, nor in such vast quantities.

Experiments as to the plans of mills have nearly ceased, so far as general principles are concerned, but improvements in details are continually being developed, especially in the "muley mills," which will be noticed farther on. As stated previously, the speed of the teeth, or rather, the number of teeth that cut in a given time, is the exponent of a saw's performance. Assuming this as the principle that lies at the bottom of their performance, we find the gang mill, by a multiplication of saw-blades, attains the highest result in this way, exceeding even the circular saw. This high rate of teeth movement is, however, not directed to speed of cutting alone, but a share of this great capacity is applied to the economy of kerf; that is, the rate of feeding is so reduced that thin blades can be used, and the gang mills of America are the only mills there in which there is not a great waste of lumber, from the kerf, and are the only modification that compares at all in economy with European mills. The hitherto cheap price of timber has made this a matter of indifference, but it is now coming to be seriously felt. During the American war the prices of everything rose to an unprecedented degree; but after a resumption of business, and when the value of the currency had risen to a gold basis, or nearly so, prices again assumed a normal condition for nearly every kind of commodity except lumber, which has not only retained its high price, but is continually advancing in value.

As said, this has directed attention to kerf waste, and a kind of saw called the double cut has been introduced, having one half the teeth inclined to one end of the blade, and the other half in the other

PLATE XXXIX.

(TRUE ELEVATION.)



BAND SAWING MACHINE.

For Slitting.—With power feed. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

direction, each way from the centre. By this means the cut is performed both at the up and down strokes, being nearly continuous. It is claimed that the dust, being discharged on both top and bottom of the log, is more readily cleared from the kerf, and that thinner blades can be used. Mr. J. Davis, the inventor of these saws, has fitted several mills with saws of No. 14 (Birmingham gauge), which is thinner certainly than has heretofore been successfully used under the old plans.

In all reciprocating machinery that has to move at any considerable velocity, the first and great law is to avoid weight in the reciprocating parts. Applied to reciprocating saws, it of course demands that the saw frames and connections be made of the strongest materials, disposed in the best manner to withstand strain. Following the general laws of construction, we conclude steel to be the strongest available material to withstand transverse and compressive strain, and the tubular form to be the best section.

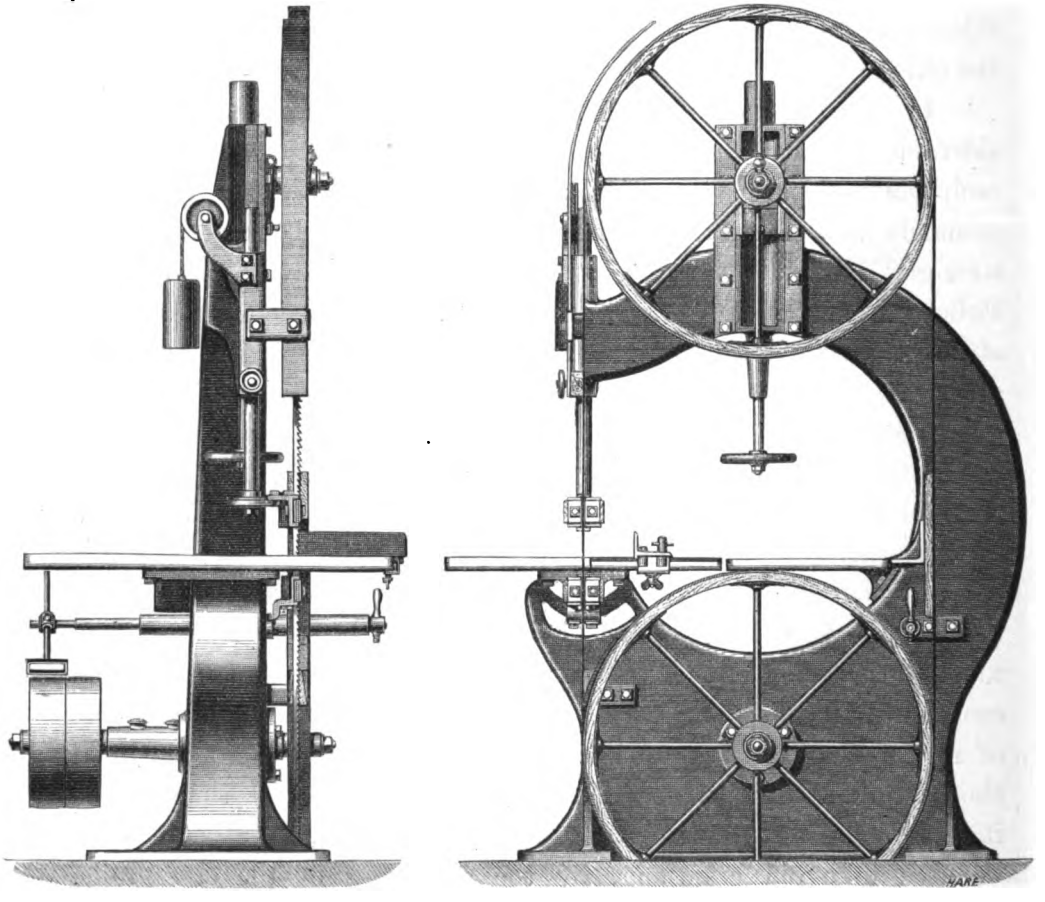
Assuming this, we may safely conclude that the frames of reciprocating saws should be made of steel, with hollow sections, instead of solid bars of soft iron, as they are commonly made. The compressive strain on the stretchers, or side rails, of a gang-saw frame is very great. Assuming it to be five tons to the blade, which is far beneath the fact, with twenty blades there would be a strain of fifty tons on each stretcher, and falling transversely on the top and bottom cross rails. This strain, too, is not to be estimated as one in a state of rest, but as the parts of a moving machine, liable to continual shocks and jars, with contingencies that may at any time double it. In mounting such saw frames in their guides, great care must be used to avoid cramping, by the springing of the cross rails, which will take place in some degree, no matter how deep their section.

The several plates represent gang mills of the most improved modern construction, by French and English engineers.

The mills are complete self-contained, to use a technicality, and differ widely from the plans of construction before noticed. To construct the gearing, or iron work for a mill, is the machinist's

PLATE XL.

(TRUE ELEVATIONS.)



BAND SAWING MACHINE.

For Straight, Curved, and Bevel Lines.—Wheels, 44 inches diameter, of wrought iron.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

business in America, the millwright being the engineer who plans and erects the mill, supplying the wood work, which is the most important part, at least the part involving the greatest amount of planning and originality. This, however, is quite a local matter, and can in no sense be understood as being a parallel for sawing machinery intended for an open market, which must of necessity be complete within itself, and framed in iron to stand the effect of climates where wood framing would be impracticable. The mills, therefore, illustrated in the plates are to be taken as representative, and present some of the best examples of modern engineering in this line.

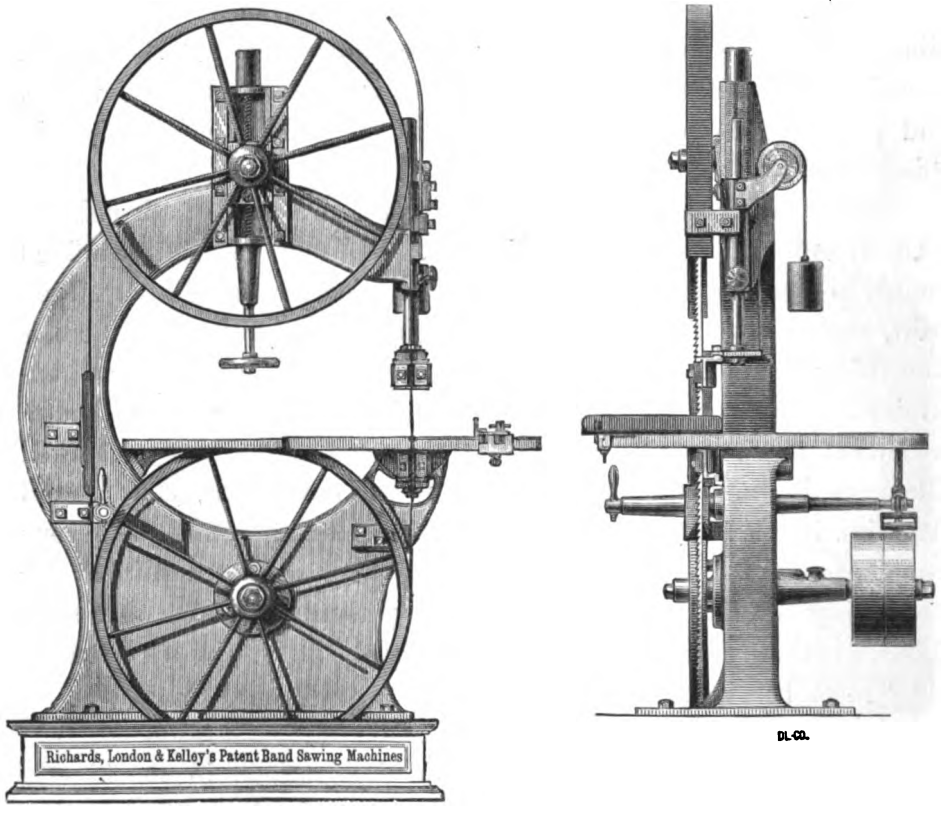
The "muley-saw mill," as it is termed in America, though for what reason no one knows, is an invention that has been confined mainly to the Western States, and has not, so far as we know, been built, nor even to any extent heard of in Europe. In fact, there is something characteristic about the bold idea of operating an unstrained saw that indicates its American origin; and, although somewhat out of place, we will in this connection note a marked difference in the estimates placed upon old customs in Europe and America in many matters connected with manufactures. The very same reasons that are adduced in England or on the Continent for continuing a plan of construction, are presented in America as a sufficient reason for changing it. In England it is said, a custom so old "must be right;" in America, that a custom so old "must be wrong," and need revolution or change.

This spirit has led to many bold innovations in machinery, among other things to the idea of an unstrained saw for cutting lumber. It is to be regretted that no engraving has been prepared of a muley mill, but it is so simple as to be easily explained.

It has been assumed that cutting speed or movement of the teeth of saws is the exponent of their performance; the muley mill is simply an expedient to increase the rate of teeth movement in a reciprocating saw, by dispensing with the tension frame and all possible weight in the reciprocating parts. There is at the lower end of the saw blade a light cross-head, mounted in guides, to

PLATE XLI.

(TRUE ELEVATIONS.)



BAND SAWING MACHINE.

For Curved, Straight, and Bevel Lines.—Wheels of wrought iron, 40 inches diameter.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

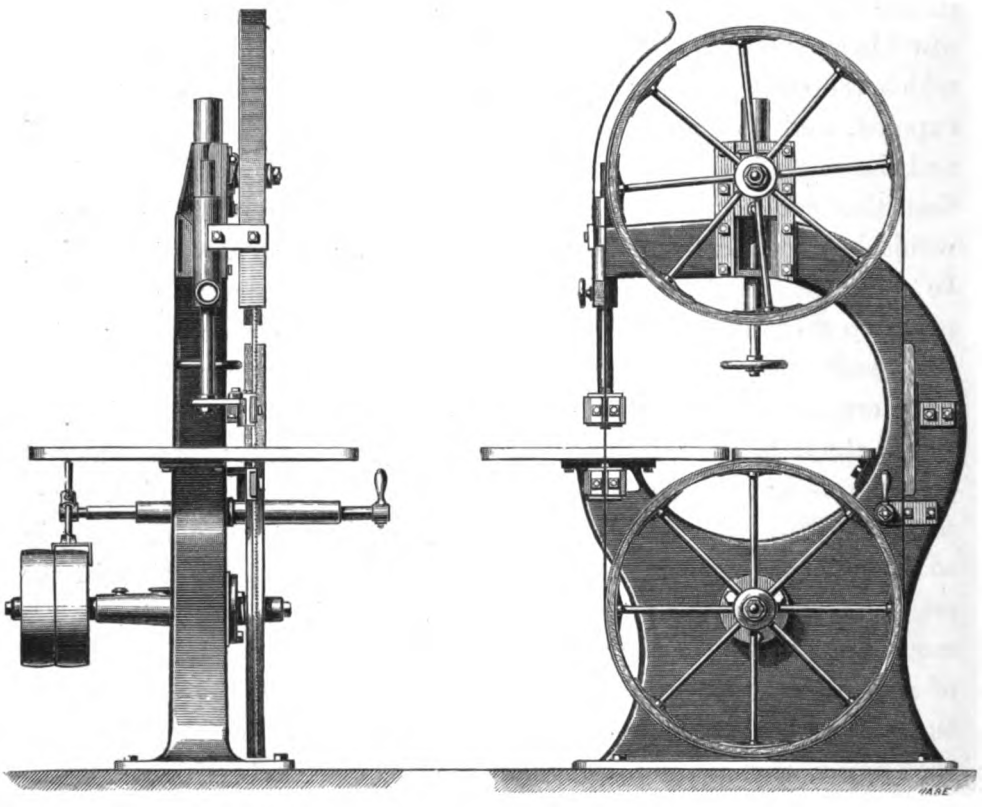
RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

which the end of the saw and the connecting rod are attached. The upper end of the saw carries another still lighter cross-head working in guides mounted on a pendent support. Immediately above and below the log the saw blade is held and guided by lateral supports of wood, with its end bearing against the plate. The lower guides are stationary, the top ones are moved to suit the diameter of the logs. Now it is easily seen that the wood on each side of the saw blade, the lateral guides above and below the log, and those to which the ends of the saw are attached, leave but little of the saw exposed, and no chance for it to deviate from its path nor to bend, and the result is that the lumber so cut is more true, as to dimensions, than that cut on mills of any other kind; just the opposite of what would be expected from the plan of operating a saw without tension. In fact, muley-sawed lumber commands in the market a superior price, on account of its regular dimensions and the smoothness, which is a result of light cutting with slow feed. Muley-saw plates, when new, are, as a rule, about twelve inches wide, and one-fourth inch thick; the stroke is from twenty to twenty-four inches; the number of revolutions from three to four hundred a minute. Such mills, when first introduced in America, some twenty-five years ago, were in some instances made on a plan termed "single geared," that is, the engine, when steam power was used, was hitched directly to the same shaft with the saw connection, and made the same number of revolutions; the stroke was short, the steam ports free; for a time the machinery would work well, but such rapid motion soon destroyed the engine, so that the plan in late years has been, for this and other reasons, abandoned. An inconvenience resulting from the plan was, that if an oil-cap, screw-nut, or other part came loose about the connections, it disappeared in a mysterious manner, and, as a rule, had to be replaced with a new one.

A prominent firm in Ohio, United States, has, however, even exceeded this idea of a single-geared muley-saw mill, so far as engine speed is concerned, by gearing its engines directly to the spindles of circular saws for lumber cutting; and has, after many years' experience, demonstrated the practicability of the plan, which, of

PLATE XLII.

(TRUE ELEVATIONS.)



BAND SAWING MACHINE.

For Curved Lines.—Wheels, of wrought iron, 36 inches diameter.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

course, greatly simplifies the mill as a whole. The engines for such uses are, however, in all respects adapted to high speed, having very free steam-passages and large bearing surfaces throughout.

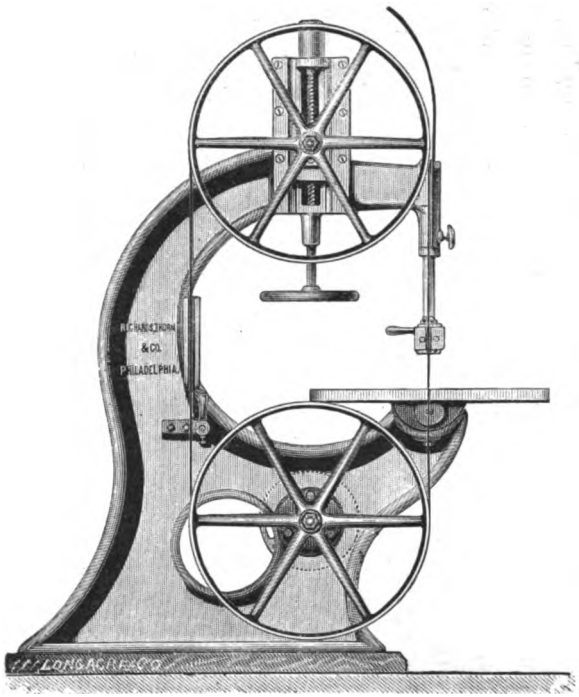
HORIZONTAL-SAW MILLS.

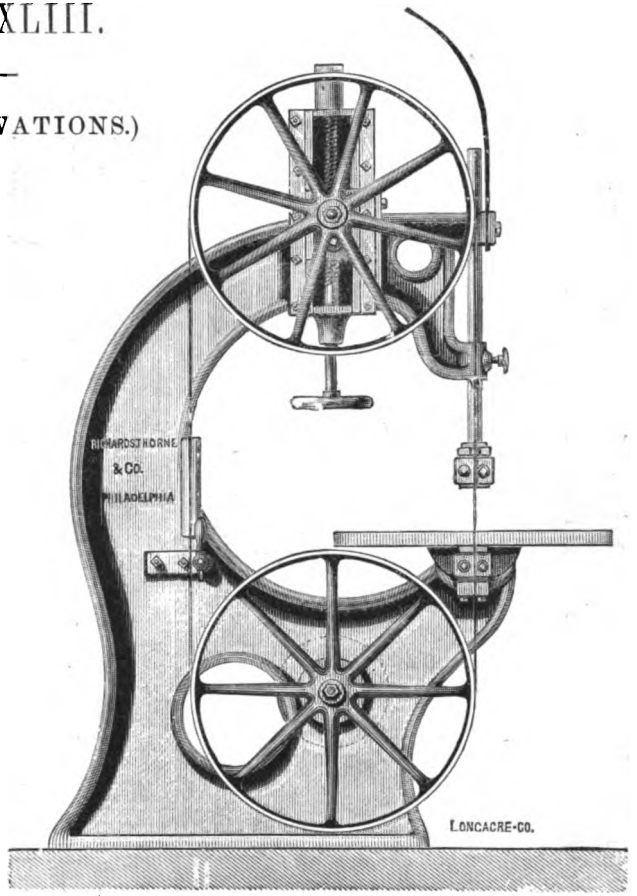
Among the engravings are two of horizontal-saw mills, a plan of construction that would at first seem at variance with many of the requirements of log sawing, and yet having advantages which may in some peculiar cases recommend them.

There are two plans of carrying a log in carriage feeding, one by supporting the ends only, which is generally known as the head block carriage, the other what is termed a face carriage, on which the timber is, to use a shop phrase, "chucked" or fastened firmly. The distinction between the two plans is, that the one guards against the springing of the stock and the other does not. Supposing a face carriage to be necessary for certain kinds of accurate sawing, there is certainly much gained in having a horizontal face on which to place the stock, and this is attained by a horizontal movement of the saw. There may, too, exist conditions in erecting that would render such an arrangement preferable. In marshy lands and on the coast in many places pits cannot be made, except at great expense, to hold machinery, and the plant, to use a provincialism, must be "spread out over the surface of the ground." In such cases a horizontal mill meets the requirements. Accepting the fact of their construction and use as a sufficient evidence of their utility, we will not notice the many objections that must be encountered, but will merely say that such mills must, with our present experience, be classed as of special construction, and adapted for special uses only.

PLATE XLIII.

(TRUE ELEVATIONS.)





BAND SAWING MACHINES.

For Curved and Bevel Lines. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

CIRCULAR-SAW MILLS.

The circular-saw mill, to employ the popular name, may be termed an American invention, or rather an American "idea," for the elements of the mill are all old, as has been shown in the history of saws; yet the bold idea of cutting large timber, and the use of two saws in the same kerf, originated in the United States, where such mills, built in a portable form, have almost entirely superseded the reciprocating mills, except at lumber centres, where a large amount of manufacturing is done with fixed plant.

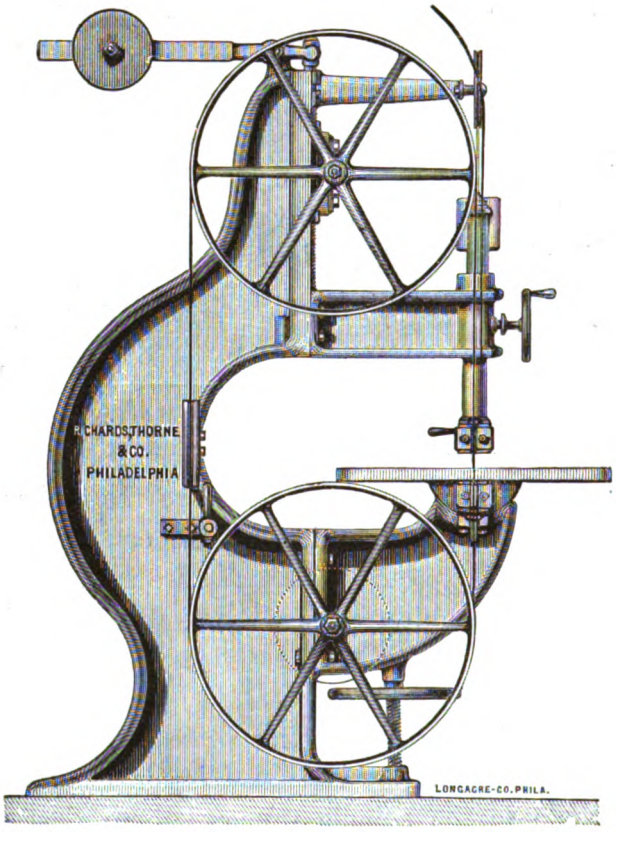
The circular-saw mill of Lane and Bodley, illustrated in the plates, is a fair sample of this peculiar mill. The framing in which the machinery is mounted is of iron, the carriage rails and supporting sills are of wood, and no foundation beyond a few cross-sleepers is needed. The engine for driving the mill is mounted on trucks, and the whole is strictly portable; it is moved to the timber as it is cut away, making an important saving in the cost of transportation. A mill of this kind is expected to manufacture from 15,000 to 20,000 feet of boards a day, requires some 40-horse power to drive it, and is attended by three men; sometimes two men will manage the mill, if the lumber is removed by other help.

The wood framing, which at first presents an idea of economy only, is, for other reasons, the best possible for a mill of this kind; we do not allude to the spindle frame, but to the carriage and guide rails, which, if made of iron, would not only be too heavy to transport and rearrange, but would require masonry foundations, to prevent their being crushed in turning squared logs, and in "rolling on" the timber. The head blocks or cross-supports seen in the engraving are of wrought iron, to guard against this; and if it were not for the elastic support given by their resting on wood at the ends, they would require a cross-section twice as great.

The manufacture of these mills has become, in the Middle and

PLATE XLIV.

(TRUE ELEVATION.)



BAND SAWING MACHINE.

For Straight, Bevel, or Curved Lines.—Table adjustable vertically.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

Western States of America, a vast business; not less than two thousand workmen are, in the State of Ohio alone, engaged exclusively on portable circular-saw mills, with the steam-engines to drive them. These engines are generally of the portable type, mounted either on trucks or "shoe rails." All the parts of the engine, with the feed and supply pumps, shaft, and pillow blocks, are mounted on the boiler, which is multiflued, with a rectangular fire-box long enough to receive "slab-wood" four feet long. The exhaust is carried into the smoke stack, creating a sufficient draught to burn the sawdust, which forms the greater share of the fuel.

When we consider that the circular saw has for a century been in use, we must look beyond the simple idea of application for a reason that prevented its use for lumber cutting until recently. Such a reason is, without doubt, to be attributed to the difficulty of following true lines.

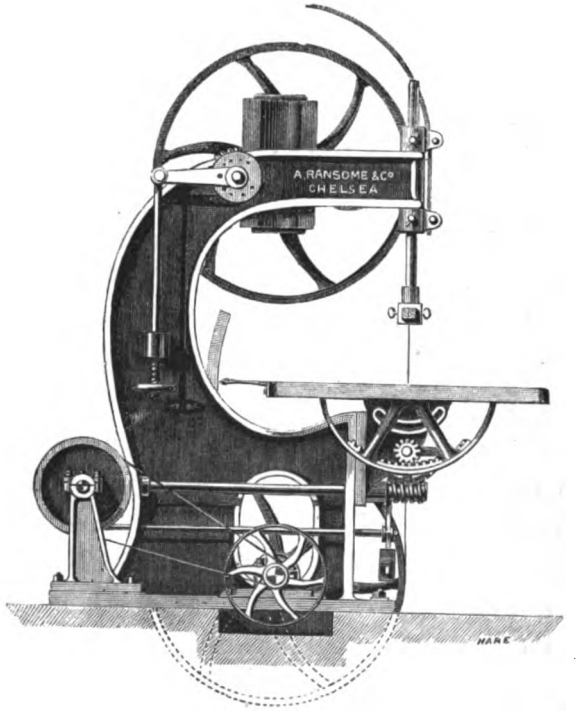
The least variation in temperature between the eye and the periphery destroys the rigidity of the plate, which is all there is to depend upon to guide it. Such difference of temperature it is almost impossible, even with the greatest care, to guard against. The heat from the mandril bearings is at once communicated to the saw-plate at its centre, while the periphery is cold from rushing rapidly through the air; or in cutting, if the wood is dry, or full of knots, a heat is generated at the teeth, and so on, through many conditions, that continually tend to a varying temperature between different parts of the plate.

At first, sawyers who had, by observation and experience, mastered the circular-saw mill, were in great demand, at high wages. In fact, it is yet a feat of no mean pretensions, to keep a large circular saw at work on rough timber; yet experience has done much to overcome the mystery of "running" a circular mill, and, like many other things, it was discovered that the trouble did not lie so much in the inherent defects of the machine, as in our imperfect knowledge of it.

Portable circular-saw mills have not yet been to any extent built in England. There is, however, a colonial demand springing up

PLATE XLV.

(TRUE ELEVATION.)



BAND SAWING MACHINE.

For Cutting Curvilinear Lines.—Wheels, from 30 inches to 42 inches diameter.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & CO., London, England.

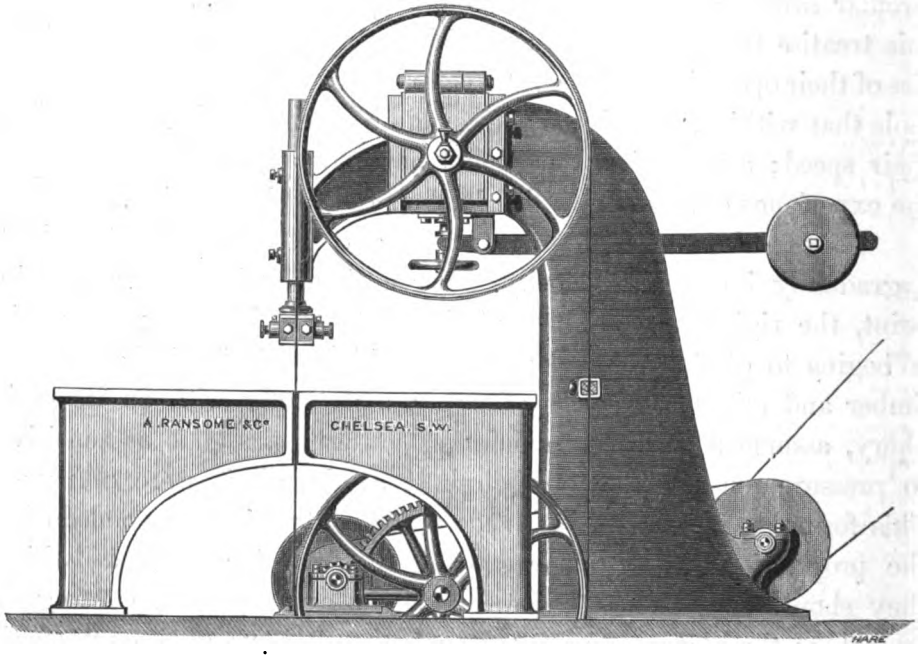
for them, which will soon produce various modifications. The mill illustrated in the plates, by Messrs. Ransome and Co., of London, belongs to this class, except as to the portability which characterizes the American machines. The character of the machinery used for lumber cutting is governed by the nature of the lumber market, the form in which it is sold and transported, its value, &c., which will at the end of this article be further noticed.

As log cutting is one of the most difficult operations to which circular saws have been applied, there is perhaps no better place in this treatise than the present at which to notice some of the peculiarities of their operation and care. Circular saws are the only wood-cutting tools that within themselves have certain inherent conditions to govern their speed; a proposition, no doubt new to many, but confirmed by the experience of any one skilled in their care and operation.

To explain, we will assume that a circular saw is started at a gradually increasing velocity. For a time, and up to a certain point, the rigidity or stiffness of the plate will increase; after this it begins to diminish, until at a very high velocity it becomes as limber and pliant as a piece of paper, and finally will, on its periphery, assume a series of undulations or waves, and is as sensitive to pressure, on the side of the plate, as though it were of paper. This forms an interesting experiment, and determines, beyond doubt, the proposition that circular saws have a specific speed at which they should run. This is, however, in a great degree, contingent upon how the plate is hammered—whether it is "tight" or "slack" on the periphery; for, assuming that the centrifugal force stretches the steel from the eye to the periphery, much would depend upon the condition of the saw at the beginning. A saw that is slack or loose on the periphery can be operated at a higher speed than one that is tight or stretched on the periphery, yet there are constant rules as to hammering saw-plates that presuppose each saw to go into use in about the same condition, and assuming this, we should have a constant speed at which saws would work best. The rigidity or stiffness of saw-plates is the most important element in their operation. It determines the thickness of the plate, and consequently the waste

PLATE XLVI.

(TRUE ELEVATION.)



BAND SAWING MACHINE.

For Cutting Metal.—Diameter of wheels, 42 inches. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

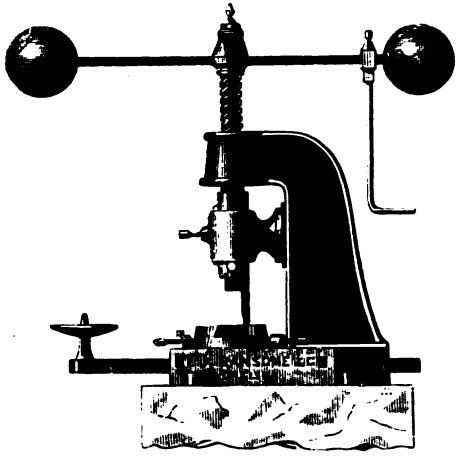
ALLEN RANSOME & CO., London, England.

of material in the kerf; it qualifies the tendency of the plate to run true; in short, it represents what we term straining or tension in reciprocating saws, with the very important difference that its degree is beyond control. We can at pleasure, and without limit, add to the tension of parallel strained saws, but can add nothing to the rigidity of a circular plate except as its thickness may be increased; hence, whatever contributes to this important matter of rigidity in circular saws should be observed in their manufacture, and the machinery for operating them. Tending to stiffen and support the plate is, first, the rigidity of the steel; second, the influence of centrifugal strain; and thirdly, lateral guides. Of the first nothing need be said; of the second, which is a condition arising out of the speed, a movement of 8500 feet a minute at the periphery is suggested. This is, of course, modified in some degree by the size of the saw and various conditions already alluded to, and can only be considered arbitrary; yet for ordinary practice the best results will be found with a speed lying between 7500 and 10,000 feet a minute.

Lateral guides for circular saws are of great importance to their perfect working, and there is no rational way of accounting for the total absence of such guides in America, where they are rarely, if ever, seen, except in log-sawing mills. Packing boxes, as they are termed by English builders, are considered indispensable, and a proof of their importance and value is found in the fact that circular saws are used of about one half the thickness that they are made in America. Saws 36 inches diameter, of number 14 gauge steel, are not unusual in England, but would in America be regarded as impracticable, as indeed they would be on the ordinary saw benches in use there. Of this matter, however, more will be said when we come to sawing machines for hand feed. In lumber or log cutting machinery, which is now being considered, lateral guides are employed in all countries, and by all makers who have constructed machinery of this kind. It is for this kind of sawing so indispensable a thing that the earliest circular-saw mills built in America were fitted with such guides. Important lawsuits grew out of patents relating to the

PLATE XLVII.

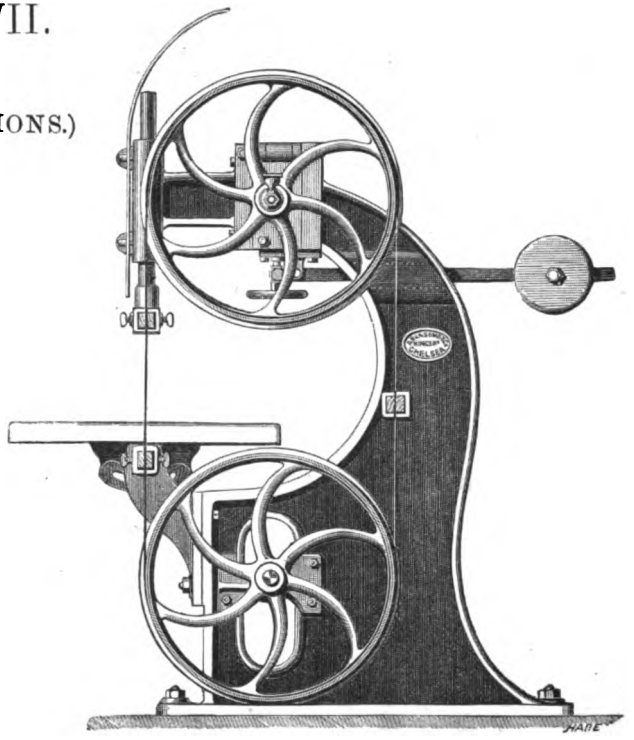
(TRUE ELEVATIONS.)



FLY PRESS.

For Toothing and Re-toothing Saws.

ALLEN RANSOME & Co., London, England.



BAND SAWING MACHINE.

For Curved or Bevel Lines. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

manner of guiding the saw, independent of its axis or spindle, which was left free to move endwise in its bearings. The plates being steadied, are guided by wood pins abutting against the plate beneath the log at both the front and rear edges of the saw. In some cases the saw spindles were mounted in bearings pivoted in radial supports, kept upright by the tension of the belt, the mandril being, aside from this, free to move endwise with its oscillating bearings. The more common plan, however, was, and is, to have the supports or bearings fixed, and to allow some end-play between the collars. There are, however, conflicting opinions as to the matter, and some builders discard the whole system of periphery guides alone, and fit the spindles of lumber or timber saws the same as those for benches, with no end-play.

The band-saw mill for timber cutting has now to be recognized among mills of this class, but will be noticed under the general head of band sawing machinery.

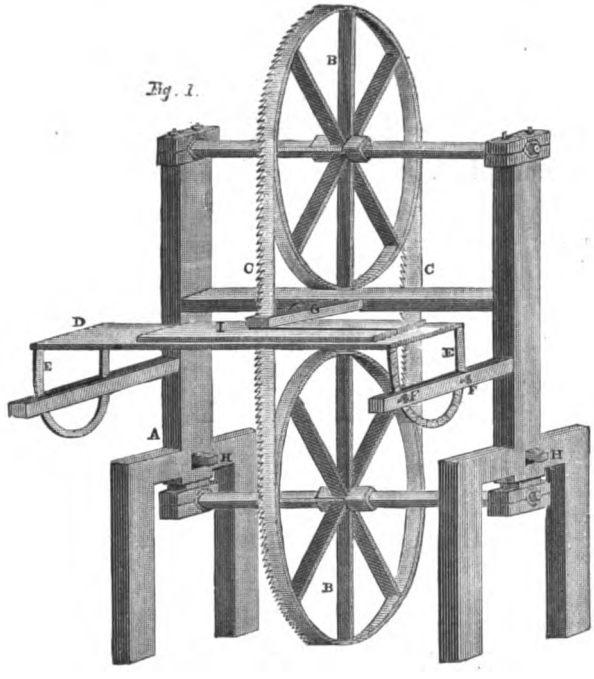
RE-SAWING MACHINERY.

The term re-sawing, although not one in common use, seems best to describe that very important class of machines used for second cutting lumber. Lumber, in its commercial form of deals or planks, is rarely adapted to use until again sawed to special dimensions, a plan that not only facilitates transportation and trade in lumber, but is the best for many other reasons. Lumber for most uses should not, when green, be cut to accurate sizes; it warps in seasoning, causing a great loss of material; besides the surfaces become so coated with dust and grit that it is more difficult to plane it after seasoning.

Timber cutting is to be considered as a preliminary preparation of the lumber for market, corresponding in metallurgy and metal

PLATE XLVIII.

(ISOMETRICAL ELEVATION.)



BAND SAWING MACHINE.

For Slitting and True Sweeps.—Supposed to be the oldest machine; had feed rolls and radius gauge.

Patented 1808 by WILLIAM NEWBERRY, London, England.

working to the furnace and rolling mill which prepare bars of various forms to be afterwards divided and shaped by the various engineering tools. Re-sawing can be regarded as the second stage in wood conversion, and comprehends a large share indeed of the popular wood-cutting machines of our day.

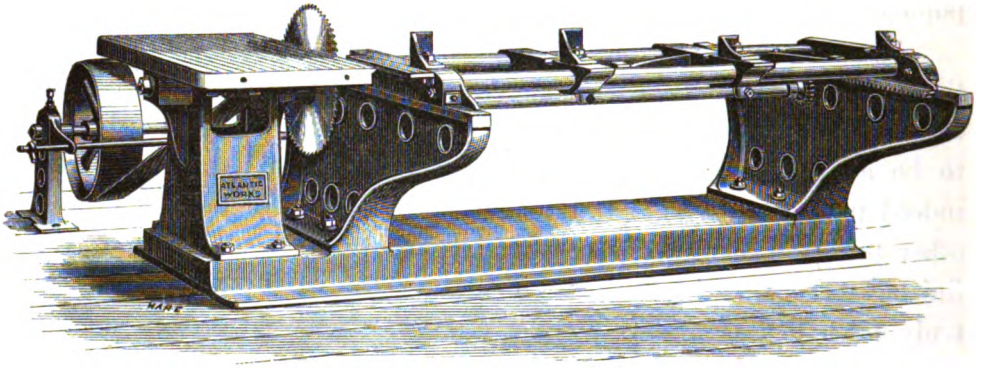
To understand the relation between timber sawing and re-sawing, the difference that exists between America and Europe in the lumber trade must be distinctly noticed; a difference so great that it is hardly to be accounted for in the fact of cheaper timber in America, nor indeed in any other way, considering the analogy that exists in most other things of the kind. Lumber manufacture, from the log to the finished state, is, in America, characterized by a waste that can truly be called criminal, and at total variance with the economy that we find practised in other things. Timber has formerly been so cheap, and the transition from low to high prices for lumber so sudden, that there has really been no time to study and develop economical plans of cutting and handling lumber. It is within the province of this treatise to point out some of the features that tend to waste, especially as any change or reform has directly to do with the machinery for manufacturing.

First we have the kerf waste. Outside of the best gang mills, which form but a small share of the whole, it is safe to assume that *one-fifth* of all the timber sawed is converted into sawdust. Considering that the lumber of commerce in America consists mainly of one-inch boards, it might even be set down at one-fourth, after the stock is squared. Circular and muley saw mills make a kerf of about five-sixteenths of an inch wide, which, with the irregularity of the lines, may be counted as three-eighths of an inch, in the manufacture of a stock into one-inch boards, and gives us five-eighths lumber and three-eighths sawdust.

This waste, although great, is by no means the only one. The system of cutting lumber to dimensions when green is another, which not only creates great waste of material but a waste of facilities and investment. Lumber sawed green must have a liberal allowance for shrinkage and warping; in seasoning boards and planks to three

PLATE XLIX.

(PERSPECTIVE ELEVATION.)

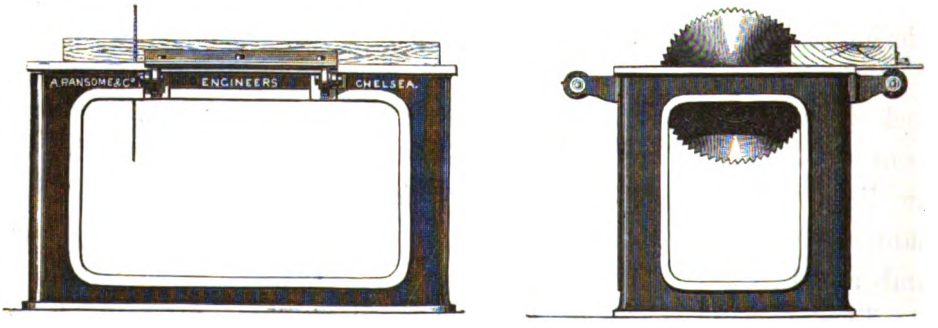


CROSS-CUT SAWING MACHINE.

With roller carriage.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

(TRUE ELEVATIONS.)



CROSS-CUT SAWING MACHINE.

For Joiners' Work. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

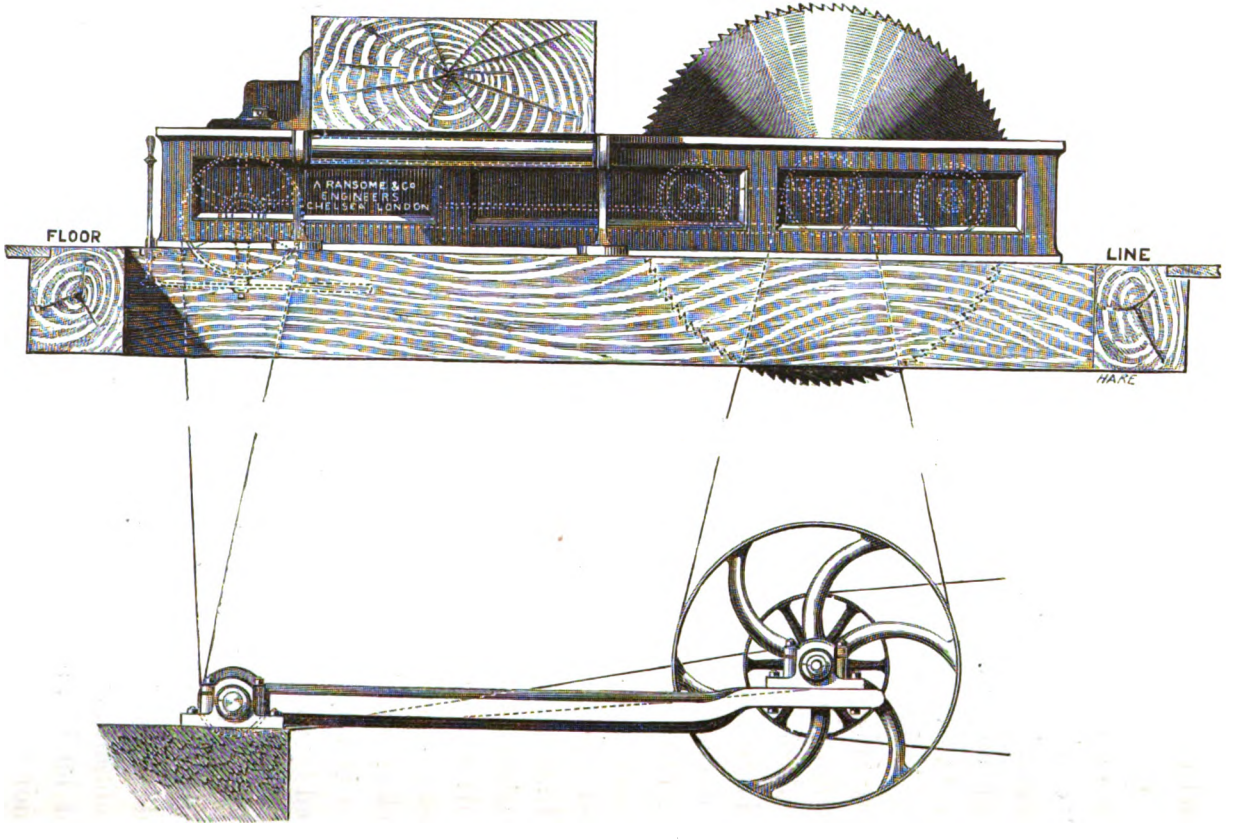
ALLEN RANSOME & Co., London, England.

inches thick it can be set down at one-eighth more to be added to waste. This eighth is, however, represented in shavings, which as fuel generates the power for re-manufacturing. It is an expensive kind of fuel, and the fact is mentioned so as not to exaggerate the faults of the system. The amount to be planed off must, of course, in "carriage planed" stuff, be enough to remove the irregularities of seasoning, and in order to protect the cutters a cut deep enough to "keep under the scale" must be taken. This scale is a formidable matter to contend with in forest-sawed American lumber, especially when it has been rafted in muddy rivers, or seasoned in open air, where it becomes loaded with earthdust, which in fir lumber combines with the pitch, and makes a compound very like vulcanite emery stone. The third source of waste lies in the amount of room required, and the large stock of lumber that has to be kept in lumber yards to meet the demands for various dimensions. A lumber yard means a large piece of ground covered with high piles of lumber of every thickness, proportioned by experience to the wants of the market; it is all forest sawed, and in many or in most cases indeed there is no saw mill attached to the yard. A fourth waste consists in the great loss occasioned by the handling of such lumber, which is done mainly by hand: not only is this waste incurred in the piling of the immense stacks seen in lumber yards, but in transportation, deals or squared stocks are mainly handled by power, or at least can be, and the difference is very much as that between coals and building stones when rated by the ton, to say nothing of the injury that the thinner grades of lumber must receive from splitting at the ends.

All this is at variance with the plans of lumber traffic and lumber manufacture in Europe, where the experience is much older, and where it has not for centuries been disturbed by extraneous conditions, such as fluctuations between the relative prices of timber and lumber, a superabundance of timber without value, &c., where it is fair to presume that the plans of transportation and manufacture are better, more economical, and representing a state of the interest that can, in the natural course of things, be expected in America in future.

PLATE L.

(TRUE SIDE-ELEVATION.)



CROSS-CUTTING SAW.

With fixed carriage and movable saw. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

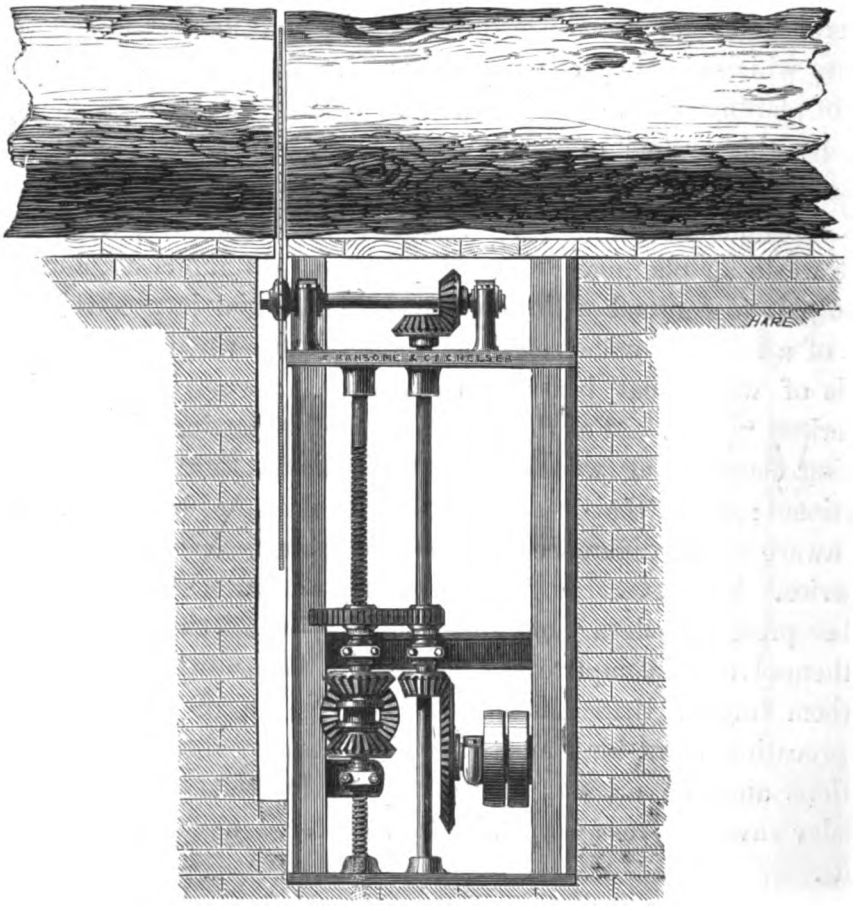
Timber comes to market in the form of deals; a lumber yard contains stocks and deals from which special orders are sawed to accurate dimensions.

Sawing machinery, or rather re-sawing machinery, is the most important part of the plant of any lumber-working manufactory, and always precedes planing and shaping machinery. In fact a general name for wood-working factories in England is saw mill, a term which certainly comes nearer a true name than the American one of planing mill would, if applied.

By this system of re-sawing it is easy to be seen that great economy is effected; the sawing machinery is so perfect and well made that the lumber is at once cut to the exact size wanted, leaving but little waste for planing. The surfaces are bright and clean, and there is no grit to contend with. No stock of material is needed beyond that of a limited number of deals and stocks of varying lengths and kinds of wood, that bears no comparison to what is needed in an American "yard." For this reason we find re-sawing machinery the leading class among wood-cutting machines in England and on the Continent; a fact that is sometimes quite strange to people who are not aware of the difference between the systems there and in North America. The several engravings of reciprocating saws for squared timber present modern types of machinery in this class, and they are in themselves so complete that there will be no need of any notice of them further than has already been given in connection with reciprocating saws for timber, from which they differ only in proportions and the manner of feeding the lumber. Band saws and circular saws for re-sawing will be considered under their separate heads.

PLATE LI.

(TRUE ELEVATION.)



CROSS-CUTTING SAWING MACHINE.

For Timber.—Arranged below the floor-line. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

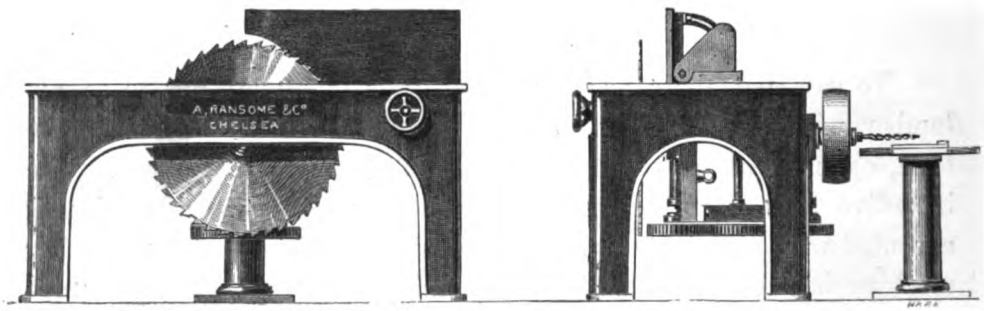
ALLEN RANSOME & Co., London, England.

CIRCULAR SAWS FOR RE-SAWING.

To say that there has been a struggle in attempting to re-saw lumber with circular saws, would be but a mild description of the time, expense, and effort that has been devoted to this object. The incentive has, of course, been the greater speed at which sawing is executed with circular saws. In America, where the gang re-sawing machine has not yet come into use, and where re-sawing is confined mainly to splitting thin boards from planks, the circular re-sawing machines have been quite successful, and are in general use for the narrower varieties of lumber, and in some cases for the deepest stuff. Messrs. Waters and Barrett, of Cincinnati, U.S., expended a great deal of money and time in an experimental way attempting to split deep lumber with the circular saw, and have certainly been successful in the kind of re-sawing to which their experiments were more especially directed, splitting one-inch boards; 15,000 to 20,000 feet a day are sawed on a single machine. The saw consists of a central disk of wrought iron, about 60 inches diameter, turned very true; on the periphery is attached segmental plates, as in a veneer-sawing machine, of about 16 gauge at the teeth. The disk and saws are bevelled off from the centre to the periphery, the lumber springing off on one side to pass the eye of the saw, which is perhaps one inch in thickness. The feed is by means of rollers, expansively geared and acting in concert with the saw spindle, from which they are driven. We notice this machine at this length for the reason that no other of similar proportions has been attempted in America. Splitting saws with power feed are, as before stated, in general use for splitting "siding," or weather boarding, and other lumber to ten or twelve inches wide; and if such machines were as carefully and accurately made as sawing machines are in England, and the packing boxes and guides adopted, saws of 14 to 18 gauge could no doubt be successfully worked in lumber to 16 and 18 inches deep.

PLATE LII.

(TRUE ELEVATIONS.)

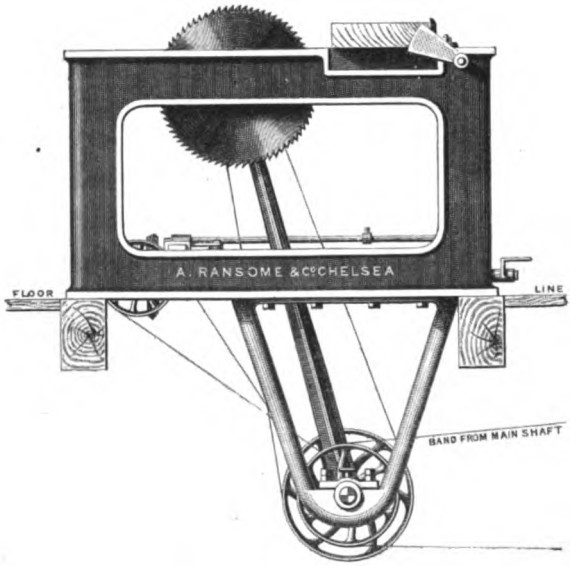


COMBINATION MACHINE.

For Sawing, Boring, Mortising, &c. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

(SIDE ELEVATION.)



RADIUS CROSS-CUT SAW MACHINE.

For General Purposes. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

Re-sawing is quite a different thing in England from what it is in America, not only with respect to the nature of the lumber traffic, but as to the depth of the lumber, which has so much to do with the nature of the machines for splitting it. A machine to work lumber 12 inches deep or 92 inches wide is, in the English market, considered as adapted to general uses. On the contrary, in America re-sawing machines to have the same range of adoption, must split 30 inches deep, and planing machines are rarely made with a less width than 24 inches. Machinery to work lumber from the Wabash Valley and in other parts of the middle States, in America, must have a maximum width of 36 inches; and even at this, boards and planks sometimes require to be split in order to be worked. The advantages, however, of working lumber of this width for any use is questionable, and the only advantage is that less is wasted in sub-dividing wide than narrow boards.

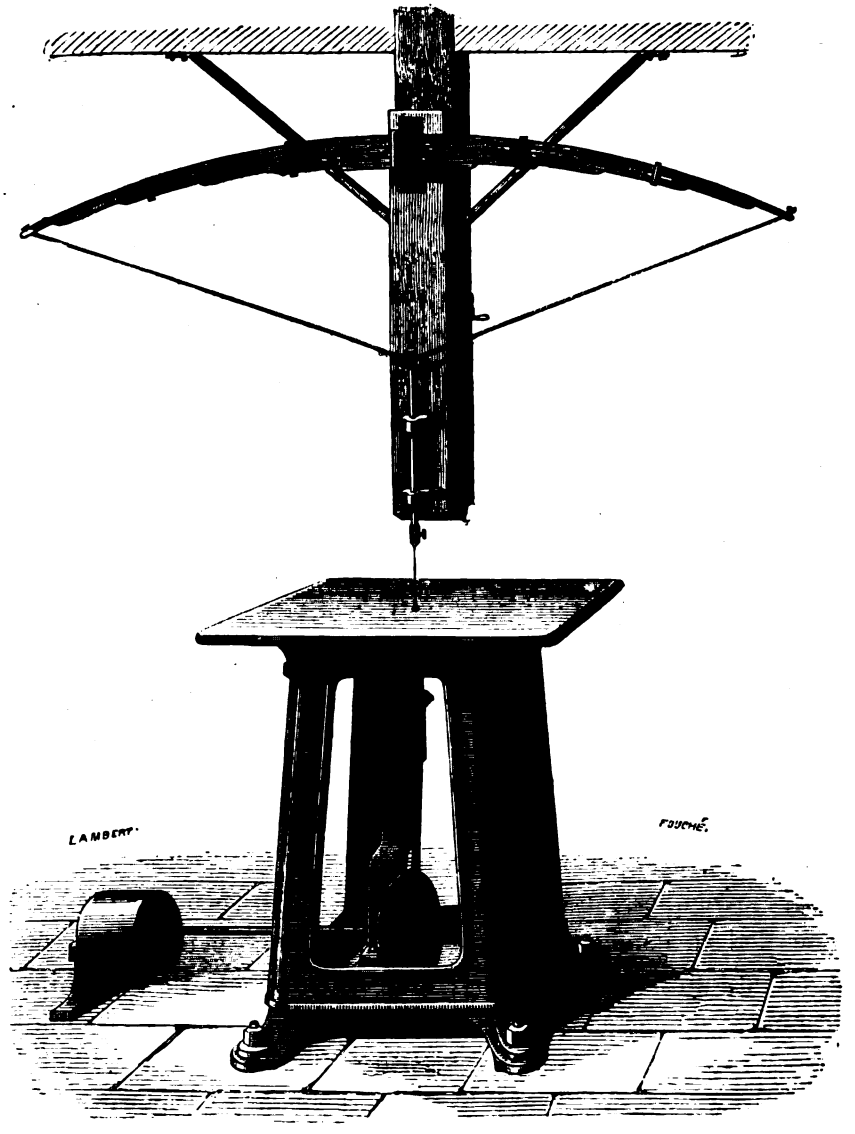
THE BAND SAW AND BAND SAWING.

The large amount of interest felt in band sawing at the present time, with the very rapid introduction of machines of this kind, will no doubt be accepted as a sufficient reason for the proportionately large number of engravings presented of machines of this class.

The future of the band saw is hard to predicate; judged upon general principles, and by the saws that govern sawing, we are at once led to conclude that it must supplant every other method. The advantages are so many, and so obvious, that nothing but insurmountable mechanical difficulties can prevent its becoming the standard saw for every kind of use. Analyzing the principles of its action, we may be said to have a blade of superior thinness, capable of tension in varying degrees, moving in right lines through the material, at a speed that is almost unlimited, and can exceed that of circular saws; operating too by machinery consisting only of rotating

PLATE LIII.

(PERSPECTIVE ELEVATION.)



GIG, OR FRET, SAW.

For Irregular and Perforated Sawing.—With spring tension.

F. ARBEY, Paris, France.

parts, and of the most simple construction, the sawdust all carried down through the timber offering no obstruction in following lines.

Add to this the peculiar adaptation of the band saw to curved lines, and its advantages cannot be over-estimated. The speed of sawing, or the cost of sawing, which is much the same thing as the movement of the teeth, is with the band saw almost unlimited. Its performance, contrasted with reciprocating saws for cutting plain sweeps or scroll work, shows a gain of time, or cost, of three or four to one, with the important advantage of being easier to operate, and we may also term it a popular machine with workmen.

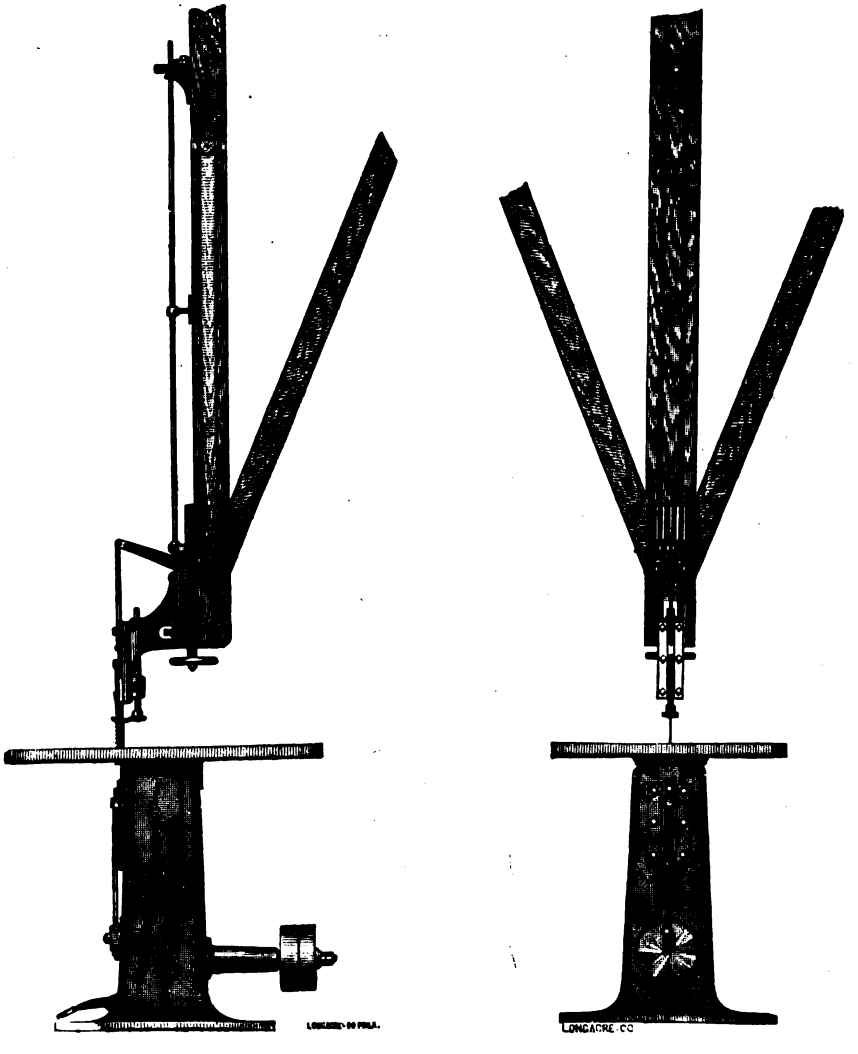
Considering these many important advantages, it would be strange and unusual if they were to be attained without combating mechanical difficulties, that must necessarily exist for a time in every new discovery. The flexion of the steel in passing over the pulleys tends to crystallize and break the saw, unless there is that peculiar degree of temper and texture which is known to withstand this bending. This has been the crowning obstacle to the introduction of band saws. It is true that saw manufacture, or steel manufacture, had not until recent years been sufficiently understood to produce perfect blades at low prices. Yet if it had not been for the fear of breaking blades, the band-saw machine, invented seventy years ago, would long since have taken its place as a standard machine for wood cutting. Joining the blades too was regarded as a most difficult operation. Holtzapfel, in his celebrated work on mechanical manipulation, after noticing the band-saw machine of Newberry, already described, speaks of it as a curious machine, and alludes to the supposed difficulty of joining the ribbons, or saws, as an obstacle to its use. That the opinion was based upon experiments we can hardly conclude, for soldering and brazing iron and steel were certainly practised at that date, and well understood.

This matter of joining blades, which will be further noticed, has disappeared as a difficulty, and become so simple a thing as to be performed in a few minutes by those that have no other knowledge of metal working.

The breaking of the saw blades by flexion, the first and greatest

PLATE LIV.

(TRUE ELEVATIONS—FRONT AND SIDE.)



JIG SAWING MACHINE.

Saws strained by torsional springs. *Stroke*—6 inches. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

objection to band sawing, is fast giving way before the improvements in steel and saw manufacture, and before improvements no less important in the machinery for operating the saws.

Joining the blades is no longer a difficulty, but a most simple operation. However there still remains another condition to be overcome that threatens to be more serious, that of resisting the back thrust in band saws. This matter would at first seem to be one of no great importance, or is at least one that would not suggest itself except in actual experiment, and hence it has not had much notice, for up to the present time the use of band saws has been almost wholly confined to scroll cutting and other kinds of work, when hand feed only has been employed, and the back thrust so inconsiderable as to cause no trouble.

When positive power feed is applied, however, a new set of conditions arise, and the question is, how to resist abrasion and heat, with a very limited amount of surface, moving at a high velocity, and incapable of being lubricated.

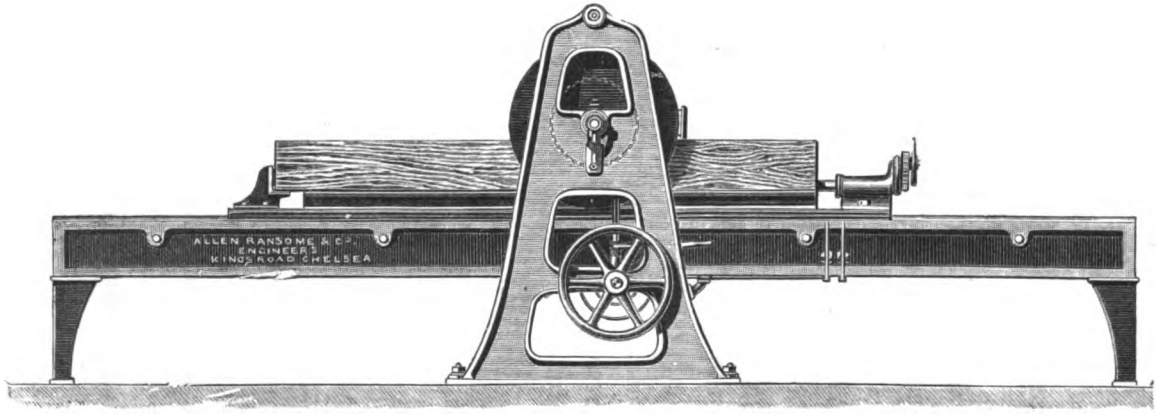
Having stated the general principles that seem to lie at the bottom of band sawing, we now come to the mechanism of machines, and the operation of the saws. Being comparatively a new thing, there is not the usual data on which to base either plans of construction or rules for operating; yet if the development of the business were waited for, there would be but little need of a treatise of any kind to give such information.

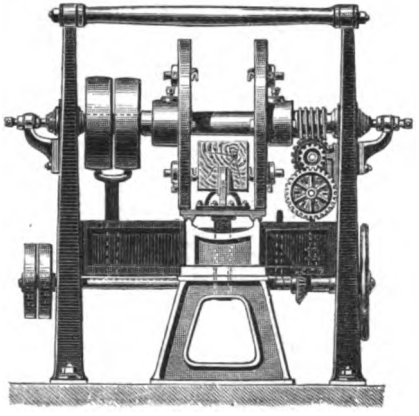
BAND-SAW BLADES.

The blades for band saws should have what is technically known as spring temper, or if different, a shade above in hardness. If much harder, they are liable to fracture from irregular tension, or concussion of any kind, expensive to sharpen, and difficult to set without breaking the teeth. Rendered softer than this, they are simply worthless, and

PLATE LV.

(TRUE ELEVATIONS.)





TIMBER PLANING MACHINE.

With transverse cutters. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

should have no market value. The amount or degree of temper in a saw blade is quite an obscure matter, one that cannot be determined to any certainty by observation, and hardly by experiment, for although a blade is properly tempered throughout nine-tenths of its length, and certain spots are drawn, as is often the case in grinding, or glazing, the blade is more worthless than if soft throughout. The purchasers of saws are, therefore, incapable of testing the quality of the saws, and at the time of buying must depend upon the good faith of the manufacturers, who usually, and very properly too, are understood as guaranteeing the saw to be of even and good temper, and of fine steel. The working quality, and indeed the whole value of the saw, is in a great measure dependent upon the care and skill of the saw maker, of which there exists no evidence, or at least no *primâ facie* evidence in the appearance of the blades when finished. In selecting band-saw blades a good plan is to roll the ends closely, and see if they will spring back to their first position. The texture of the steel can be examined by breaking a short piece from the end, the difference between coarse granular fracture, and fine lively-looking steel being familiar matter to most mechanics. To determine the straightness of the blade if not joined, unroll it on the floor, and by "sighting it," irregularities are easily detected.

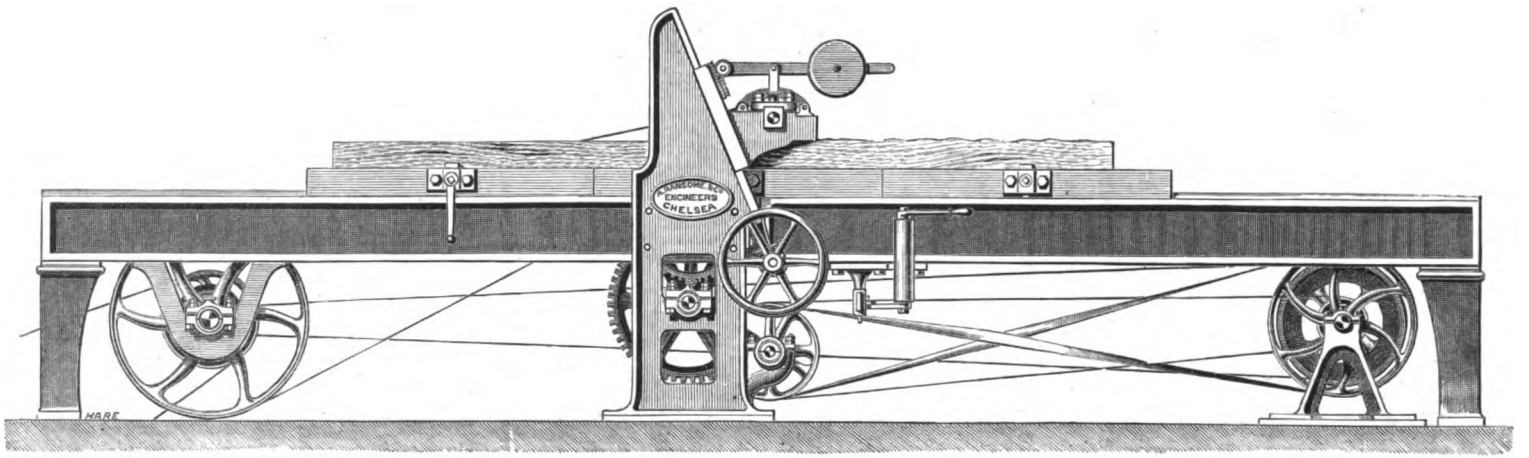
Another most important matter is an exact parallel as to width; the slightest variation in this regard becomes a serious objection to the operation of a saw, producing scratches on the work, irregular action of the teeth, and consequent irregular tension of the blade through its cutting at intervals only.

Any variation of width between the two ends of a blade can be easily detected by lapping them, and placing the points of the teeth on a plane surface, which will show on the backs any difference of width, however little it may be.

The pitch, depth, and form of teeth for band saws, is a matter about which there is such a diversity of opinion, that the only safe inference is, that it is either a matter of no great importance, or else not understood. We allude of course to saws for special purposes; for various modifications of the teeth are needed in different cases,

PLATE LVI.

(TRUE SIDE ELEVATION.)



DIMENSION PLANING MACHINE.

For Timber of Rectangular Section.—Has carriage feed on cross cylinder. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

and unfortunately the condition that has most to do with the change is continually varying, that is, the depth of the lumber. In considering saw teeth, we have first, pitch (distance between teeth); the inclination on front and back of the tooth (cutting angle); the form of the gullet, as it is termed, for holding the dust; the width of the base of the tooth, so as to give sufficient stiffness to retain the "set"; and the kind of set given to the teeth.

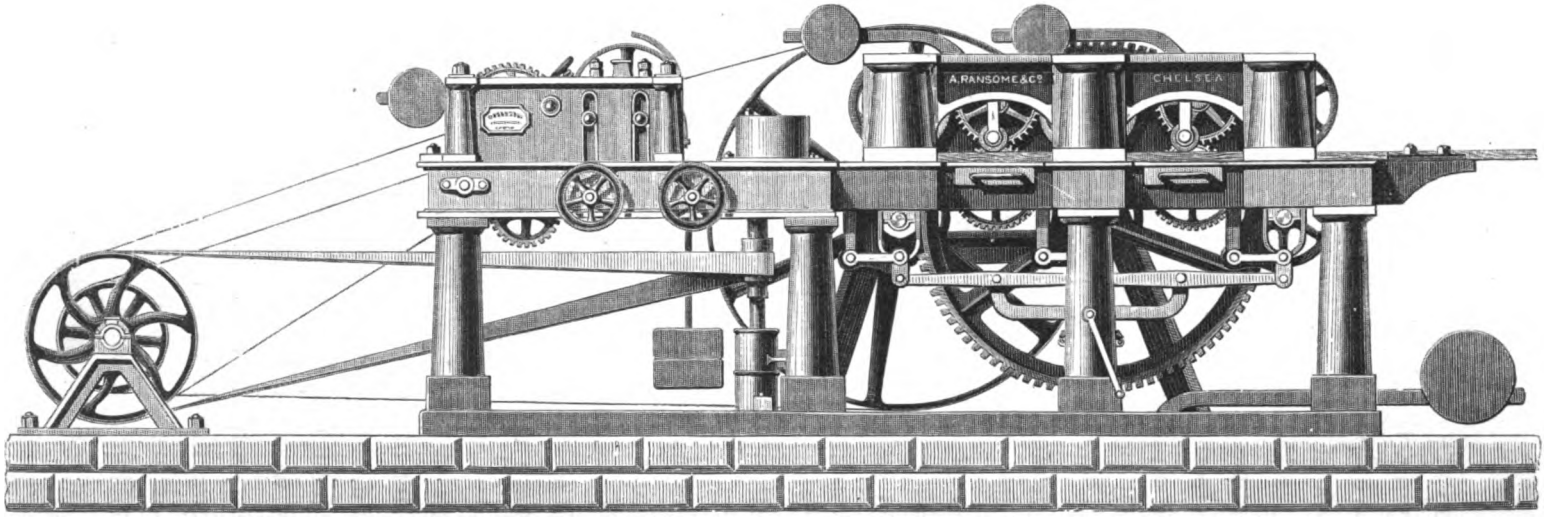
It would be supposed that the experience of operating other saws would furnish all that could be learned of band saws, but this does not seem by any means to be the case. The thinness of the blades calls for every minute condition that will tend to keep them true, and to run in line. With a thick circular, or reciprocating saw, the case is different: it can be forced to its work, and made to operate without that nice regard to the condition and form of the teeth that must be observed in band sawing.

For soft wood, a pitch equal to one-half, and a depth equal to one-fifth of the width of the blade, is as near a general rule as can at this time be suggested. For hard wood a closer pitch of one-third the width is better. The gullet or throat under the tooth should in all cases be circular; not only to guard against breaking or checking in the corners, but to prevent the dust from lodging; as with an acute angle it can be carried in quantities on to the wheels. For the front inclination of the teeth, it should be sufficient, so that when the saw is sharp there will be no back thrust on blades; a thing that must in each case be determined by the observation of the operator, and the character of the timber to be cut.

In the matter of setting, it must be determined by the thickness of the blade and character of the wood. In sawing pine, or other soft woods, the teeth can be bent from the base, and will retain their set; but in hard wood or knots this kind of setting does not last long, but soon "comes out," to use a lumberman's expression. Upsetting the teeth is impracticable with thin saws, or at least is very difficult, unless the plates are No. 14 or thicker. The temper besides is, or ought to be, too high in band saws for upsetting. The best plan of setting developed in the writer's experience, in band sawing, is a

PLATE LVII.

(TRUE ELEVATION.)



ROLLER-FEEDING PLANING MACHINE.

Intended especially for Soft Wood.—With fixed cutters. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

quick abrupt bend on the bottom of the tooth by "sharp blows" from a light hammer—setting the steel, as it were, off to one side and raising a kind of scraping edge on the cutting side of the tooth.

It is easy to get a regular or smooth set in this manner, and it requires no special skill to perform it; it is besides sooner done, no gauge being required. The saw is passed over an anvil, with its top bevelled to a proper angle, the bottom edge of the tooth projecting over the bevel, from a sixteenth to one-eighth of an inch, according to the amount of set required.

These remarks upon teeth relate to saws intended for power or positive speed. For scroll sawing or plain hand slitting it is presumed that no information of any interest could be given, and that none is needed.

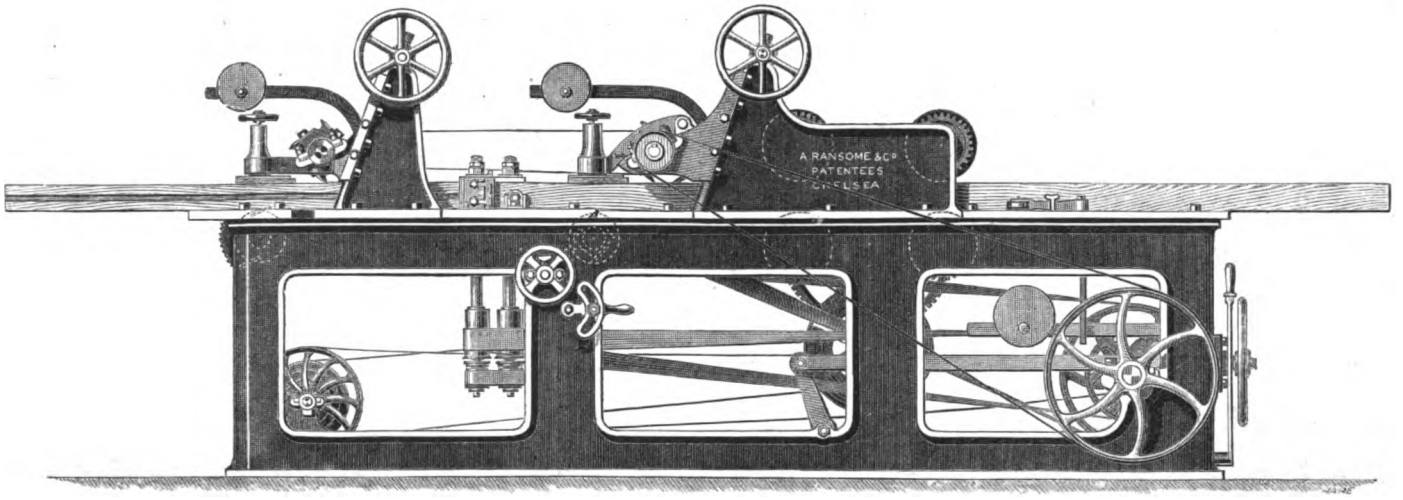
JOINING BAND-SAW BLADES.

The operation of joining band-saw blades, that at first seems so mysterious to those unused to brazing and soldering, is extremely simple when once learned. A few failures may be expected in the first experiments, and the letters received by the manufacturers of sawing machinery from their customers relating to this matter are sometimes quite humorous, and not unfrequently contain practical suggestions of great value, that have been overlooked in the workshop by the builder.

Brass, spelter, German silver, and various alloys are used for making the joints. The preference being generally in the end given to the silver solder, on account of its convenience and the low heat at which it fuses, compared with brass. Its strength is quite sufficient, although not equal to brass; in fact the joints, however made, rarely give way, the weak points being where the annealed or soft steel meets the tempered, or unannealed portion of the blade: by a little dexterity, however, and after some experience, the temper can be restored at this point, by applying water while the blade is yet hot, a plan that is now commonly practised.

PLATE LVIII.

(TRUE ELEVATION.)



PLANING AND MOULDING MACHINE.

With roller feed; has six cutter heads. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

Joining saw blades, however, belongs to the saw maker, and the necessity for doing it in the workshops is owing to the frequency of breaking the blades, which will no doubt be overcome in time.

To make a joint with silver solder or German silver, the solder should be rolled into thin sheets; the saw being scarfed or bevelled off to about one-third of its thickness at the ends, and cleaned with acid; the solder is placed in the joint, the piece being large enough to project on all sides: the joint should then be clasped with a pair of heavy tongs, heated to a full red heat, and held until the solder is well melted and runs out of the joint, when the tongs can either be suddenly cooled with water, or removed, as the case may be. For heavy saws of four inches or wider, there should be provided two pairs of tongs, the heated pair being generally too weak when red hot, to close the joint; the second pair is clasped over the hot pair from the opposite side, and gives the compression needed to close the joint.

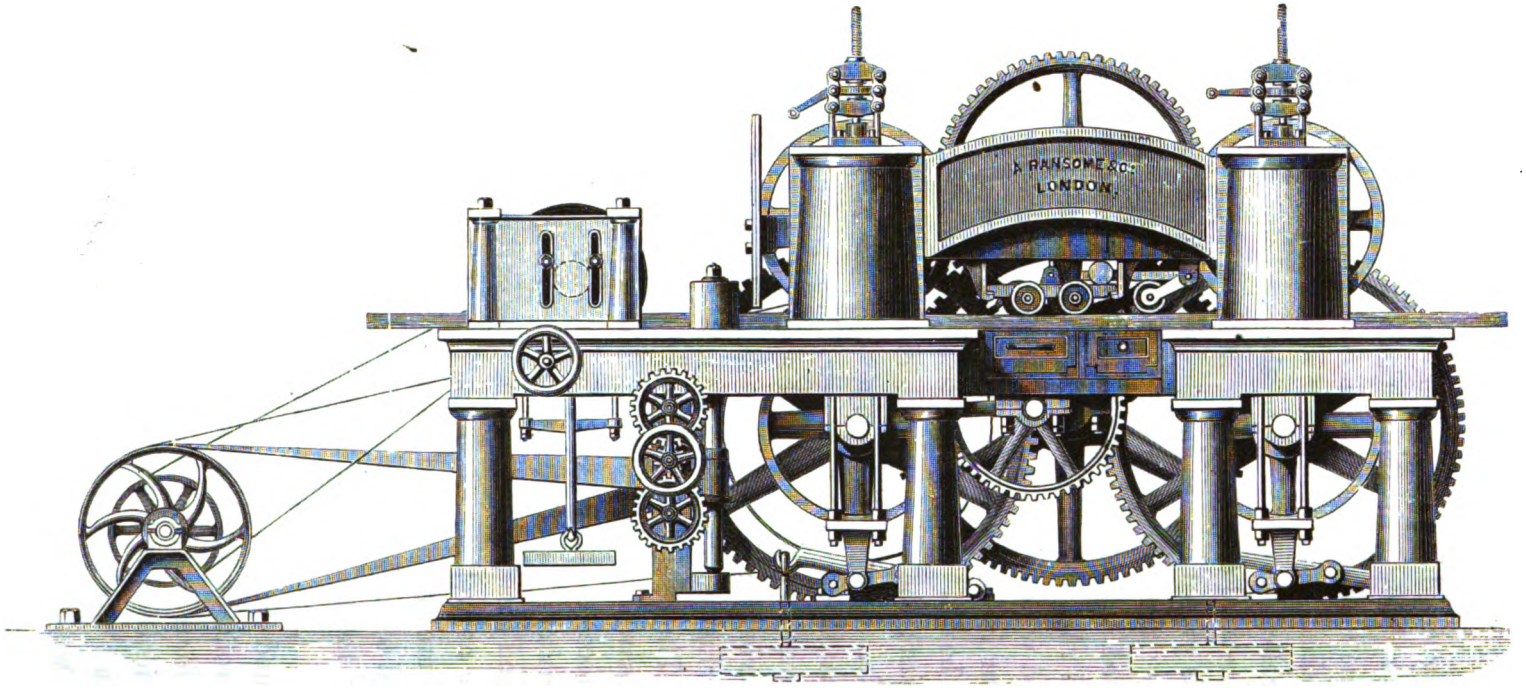
The manufacture of band-saw blades requires the most careful and intelligent manipulation, with a great deal of what may be termed special knowledge; so much so, that their manufacture has become quite an exclusive thing in Paris, where they are nearly all made at this time. The steel for the larger plates, and indeed for the greater number of saws, is made now in England, but the tempering and smithing processes remain with the French.

Saw makers sometimes contract with French houses for steel, tempered and ready for toothing and grinding processes that can certainly be as well done, and much cheaper in France; the object being to secure the name of manufacturing band saws. This plan is likely to lead to doubtful results, owing to the great danger of drawing or injuring the temper by those who do not understand the entire process.

Perin and Company, of Paris, were the first to manufacture blades that gave profitable results; being also the manufacturers of machines, and indeed for a long time the only manufacturers of such machines. Their experience in operating the saws combined with great care and perfection in their manufacture, have rendered Perin's blades famous all over the world.

PLATE LIX.

(TRUE ELEVATION.)



ROLLER-FEEDING PLANING MACHINE.

For Heavy Planking.—With fixed and rotary cutters. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

BAND SAWING MACHINERY.

Band sawing machines are divided into two classes, the scroll-cutting or hand-feeding machines, and machines with positive or power feed for cutting logs and deals, or re-sawing planks, &c.

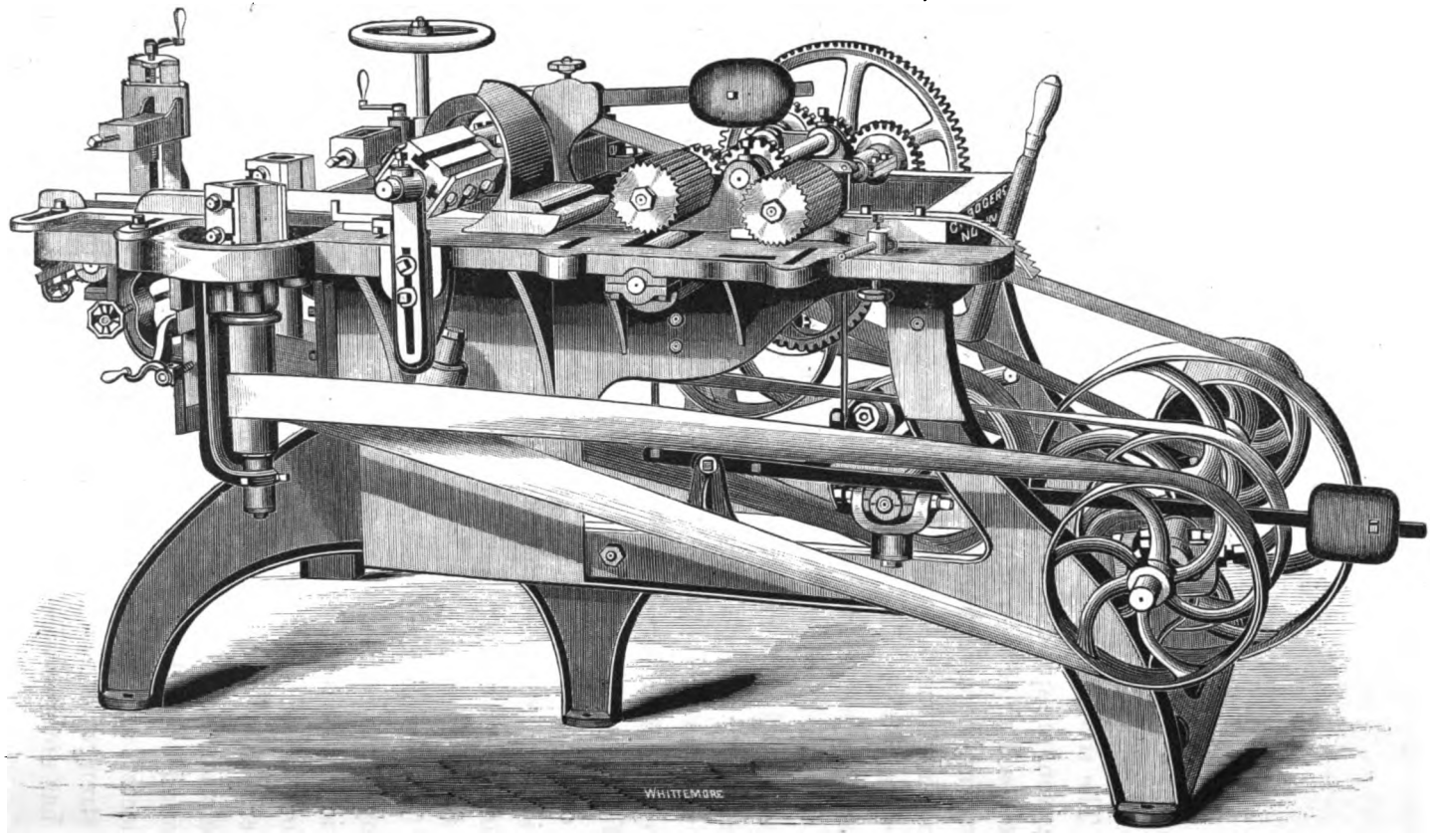
The scroll-cutting machines, of which a number of illustrations are given, are quite a perfected class, considering the short time that has elapsed since their introduction. Simple in their general functions, there was, however, much to be learned by experience in building them, and numerous small improvements have from time to time been added, until there does not seem to be much room for further change in the machines of the best makers.

Ostensibly a band-saw machine consists of two wheels with a saw surrounding them as a band-axial shaft, and a frame to support them. Practically a band-saw machine is a great deal more than this, and involves the tension and "edge curvature" of the blades, strength of framing, elasticity of the wheel, supports independent of the frame, back supports and lateral guides for the blades, construction of wheels, with many other things, all of which must be carefully considered and well understood before we can look for anything like a standard of construction for the band saw, simple as it may seem as a finished machine.

The framing, which we will first notice, has to be heavy and strong, a proposition that seems to be at variance with the idea of elastic tension on the blade, but must not, as we shall see, be at all confounded with it. The framing has to "surround" the work, or rather, the work has to be performed in the throat of the frame; any correlation between the top and bottom guides must be established "around" this throat; in other words, the top and bottom guides are connected, and keep their relative positions, by means of the rigidity and strength of the framing surrounding the open throat, a matter that has nothing whatever to do with the elastic tension on the blade.

PLATE LX.

(PERSPECTIVE ELEVATION.)



MOULDING AND PLANING MACHINE.

To Plane Four Sides.—Has overhung heads, with the vertical spindles adjustable to angles for bevel faces.

C. B. ROGERS & Co., New York, U.S.A.

Secondly, the strain upon the frame is torsional, one of the hardest to withstand, especially at such long distances. The strain of the blade falls outside of the frame, as can be seen in the elevations, a necessity that arises out of mechanical conditions, more important than the extra material needed to carry out the arrangement. For the frame to yield in the slighest degree would at once change the relative position of the guides, causing "edge curvature" and certain destruction of the blade. The top wheel would also be thrown out of line, and lead the saw into a strained position.

Analyzing the matter in this manner, no one with the most elementary knowledge of mechanics can confound the two—the conditions of "elastic tension" for the blades, and elasticity in the frames of band-saw machines. They are two independent things, between which there is indeed no relation that should lead to confusing them.

To resist transverse and torsional strain, it need hardly be said, that a cored or tubular section is the best form of framing. The difference is so extraordinary in this regard between the rib and cored frames, that it would be almost incredible, if we had the precise data to express it.

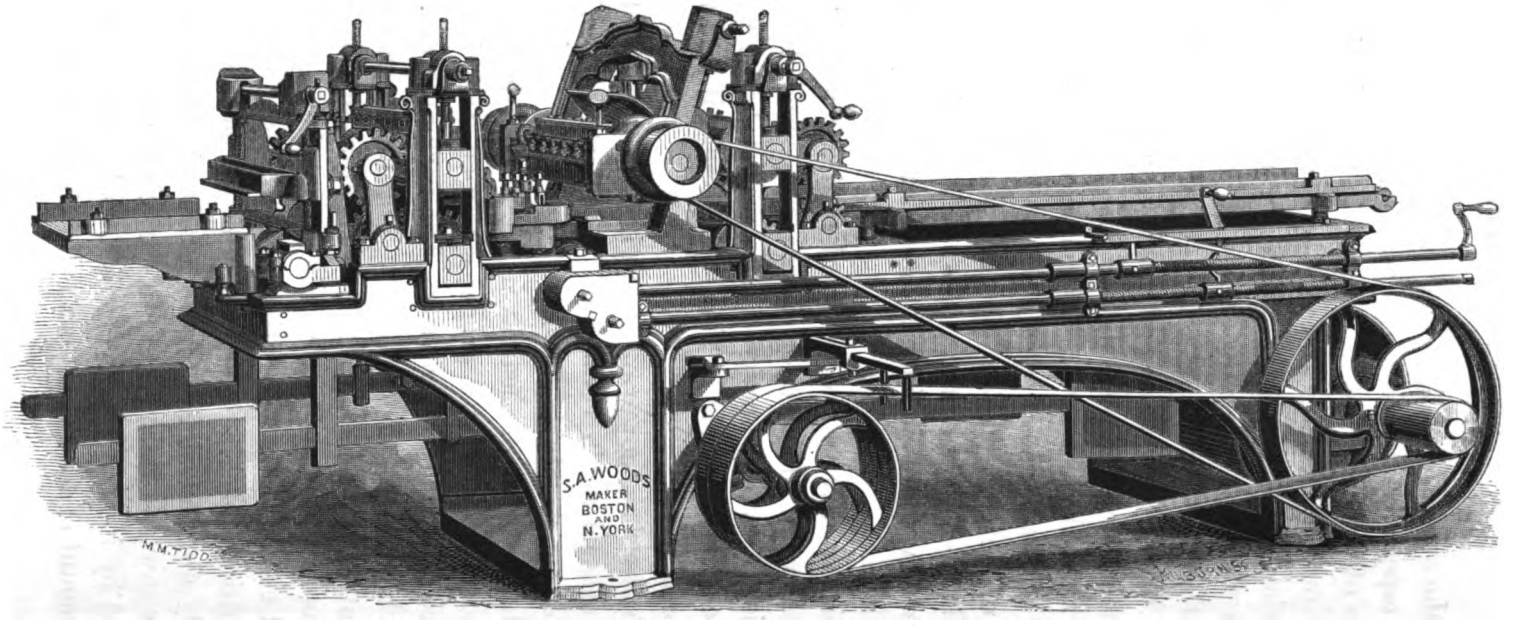
The matter has, however, before been alluded to at length, and is only mentioned again because of its importance in the particular case of band-saw machine frames.

A certain amount of elasticity in the tension devices for straining band saws is so obviously a proper condition, that it would hardly seem to need experience to prove it. The varying temperature of the blade, which, considering its length, is quite an important matter, and the want of care and judgment in adjusting, demand such an elasticity as will maintain a "uniform tension." For very long blades, and especially with positive feed, a weight is preferable; but in scroll-cutting machines, or blades of 25 feet or less in length, springs only are needed, if proper attention is paid to the connection between the saw and the springs, so that their action is not cramped or destroyed by intervening mechanism, as is often the case.

The amount of tension on band saws is a deceptive matter, being

PLATE LXI.

(PERSPECTIVE ELEVATION.)



PLANING MACHINE.

For Flooring-boards, Moulding, &c.—With four cutting cylinders.

S. A. WOODS, Boston, U.S.A.

considerably more than would at first be supposed. A thousand pounds of tension on a blade one inch wide is a small matter, while with blades of five inches wide two and three tons are needed. It is, however, impossible, and we might add, useless, to give rules in a matter which must in each case be governed by the judgment of the operator, and the nature of the saw and its work. Any experienced sawyer knows by feeling the blade when it is strained enough; besides, in the experience of operating band saws for lumber cutting there have thus far arisen in the matter opinions that are at total variance, and that need longer time and more experience to reconcile, before any rule would have interest or value.

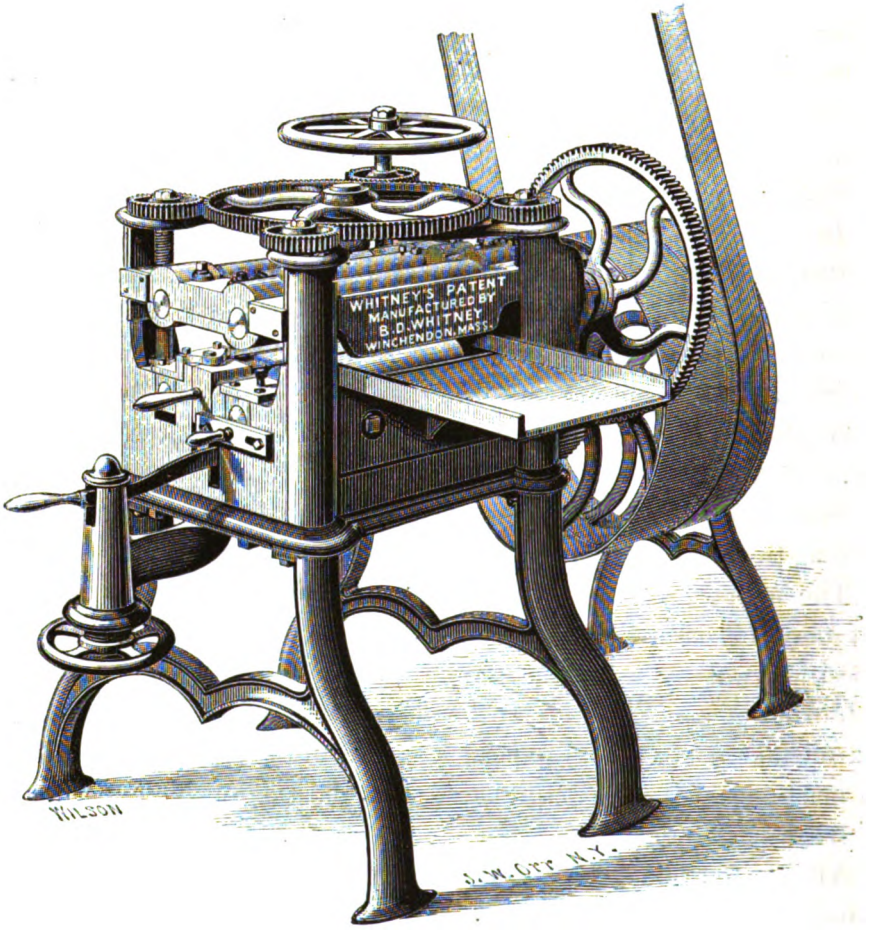
In band-saw mills built and used in the State of Indiana, America, the saws are operated almost without tension, somewhat on the principle of the muley saw. In another case in the city of New York we find them operated with the highest tension possible, and with *rigid* mechanism for straining. In the first case saws of five and even six inches wide are used, in the second about three inches wide. Here we have opposite and contrary conditions of operation both successful, which only argues that there is yet much to learn in the matter that will have to be developed by experience.

The support of the blades in band-sawing machines involves what may be assumed as the vital question of their success. This proposition was made by the author some two years since, through the Journal of the Franklin Institute, and was received as a novel, if not a mistaken one, but an experience since in designing and building such machines, that has comprehended the most extensive experiments ever tried, has confirmed it.

All the various mechanical conditions of band sawing give promise of successful solution, except that of resisting the back thrust of the blades. To state it in general terms, we have in the case a surface contact with pressure and motion that far exceeds that of any bearing, in fact has scarcely a precedent, with a total want of the conditions that are needed to meet it. The area of surface is, for instance, limited—almost an edge; lubrication is out of the question. Rolling contact too is inadmissible under any considerable

PLATE LXII.

(PERSPECTIVE ELEVATION.)



SCRAPING, OR SMOOTHING, MACHINE.

For Smoothing and Finishing Surfaces.—Has fixed cutters and continuous feed.

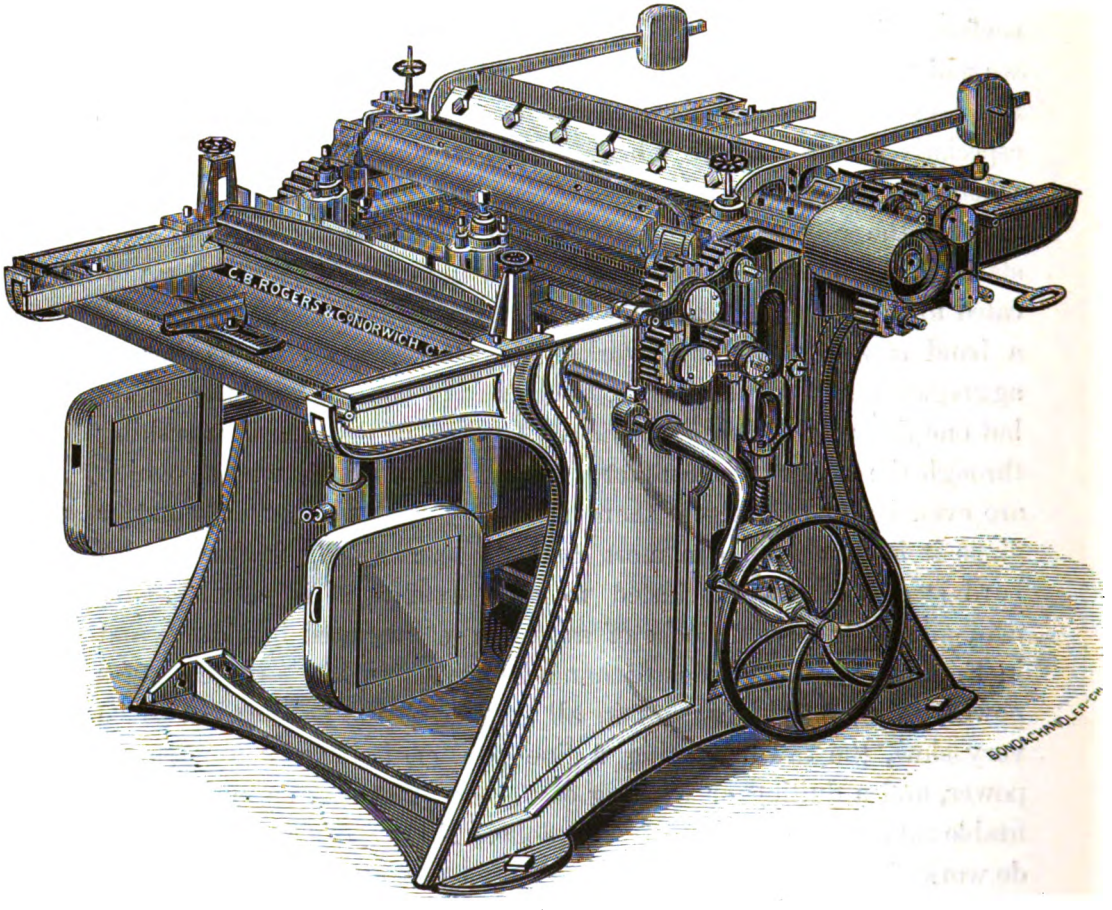
B. D. WHITNEY, Winchendon, U.S.A.

pressure, and there seems to be no feasible way of meeting it with devices that will be durable and resist abrasion. One thing, however, is favourable, temperature can be controlled, and is by the very nature of the operation kept down; this fact alone is all that can give us hopes of successfully resisting back-thrust of band-saw blades, for no considerable or rapid abrasion takes place between metallic surfaces without heat. The combination of tempered steel with what we will term hardened steel is one that gives, under certain conditions, the best results known in the way of resisting wear and abrasion, especially in cases where lubrication is impossible or imperfect, and when heat can be avoided.

In the case of wood saws the heat created by friction upon stationary guides is carried off as fast as generated, being communicated to the air, or to the timber if the latter be green or damp. With a band saw 40 feet long, working against back guides having an aggregate length of ten inches, the saw is in contact with the guides but one *forty-eighth part of the time.* The rest of the time it is rushing through the air, or is in contact with the wood, or the wheels, which are even better conductors than the air. From this fortunate matter alone it is practicable, in most cases, to resist the back thrust with hard steel surfaces, lubricated to such extent as is possible, and managed with care. Blocks of wood are mainly used in France and in England for the guides of hand-feed machines, in some cases for power-feeding machines; but in all such cases the cutting has to be very slow, the sawdust being a fine powder, indicating a waste of power, and a dulling or wearing of the saw, that bears a most unprofitable ratio to the amount of work done. No saw can work well, nor do work cheaply, when each tooth does not perform a fair share of the work, a matter that is in all cases indicated by the sawdust. As an old miller examines the flour as it comes from the burrs, so an experienced sawyer examines the sawdust to see how the saw is working. There is no question but that in band sawing, except when the saws are newly sharped, there must be a certain amount of forcing to keep them to the wood, and this forcing is represented in the back thrust against the guides.

PLATE LXIII.

(PERSPECTIVE ELEVATION.)



PLANING MACHINE.

Adapted for Light Work, to 24 *inches wide.*—With surfacing and edging cutters.

C. B. ROGERS & Co., New York, U.S.A.

M. L. Orton, of Philadelphia, U.S., suggested some time since (1871) a device for resisting the back thrust of band-saw blades that may become a successful expedient. Its ingenuity will be a sufficient warrant, if it had no other claims, for mentioning it here. It is evident that in forcing the blade forward, in the direction of its breadth, we have only the surface of *its edge* to work with, representing a line the length of the guides, and of a breadth equal to the thickness of the plate, or in an ordinary log saw say a total of about *five-eighths* of an inch of area. To evade this Mr. Orton proposes "griping rollers" on the sides of the saw, covered with some elastic material, and with their axis on such an angle with the blade that they will carry the saw forward into the wood; the degree of pressure or griping force of the rollers to be governed by the amount of the back thrust of the blade; or, in other words, as the blade may move back from the wood it will by contact with a back guide close or cramp the rollers on its sides, which will at the same time answer for lateral guides. The idea is certainly an ingenious one, and aside from the high speed at which the rollers would have to run seems to be practical.

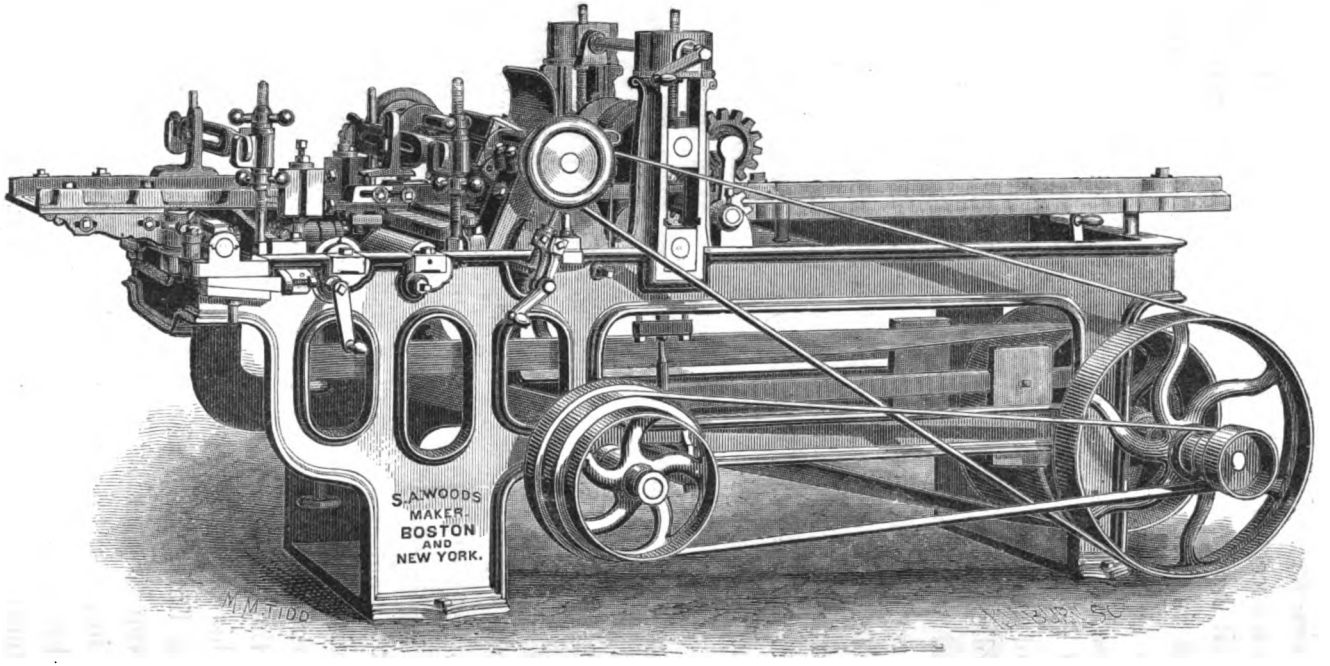
Richards, London, and Kelley, of Philadelphia, employ in their band sawing machinery back supports of hardened cast steel, consisting of a round pin or cylinder set parallel with the saw, that can be adjusted by rotation, so as to present a great amount of wearing surface. For their larger machines, that have power feed, these hard steel cylinders are bored out hollow throughout their length, and are filled with tallow, which, in case of heating, is melted and runs out through small holes drilled transversely, and by means of annular grooves to the back of the blade.

With this imperfect notice of a matter in which there has been as yet but a limited experience, we leave it, feeling that but little has been given where much is required, and that for the future it will be the most important question affecting the use of the band saw where positive feed is used.

The lateral or side guides for band saws present no mechanical difficulties. The pressure is slight and variable, and there is ample

PLATE LXIV.

(PERSPECTIVE ELEVATION.)



MOULDING MACHINE.

***Adapted to the heavier class of Mouldings.*—With four spindles.**

S. A. WOODS, Boston, U.S.A.

surface over which it can be distributed. For narrow blades used in scroll sawing hardened steel makes the most convenient guides. A series of leaves of one-eighth to one-fourth in. in thickness, the bottom or first one being of hardened steel, the rest of peat wood, is perhaps the best arrangement that has yet been invented for fixed guides. This matter is, however, treated of under the head of bearings, and applies to band-saw blades in all respects.

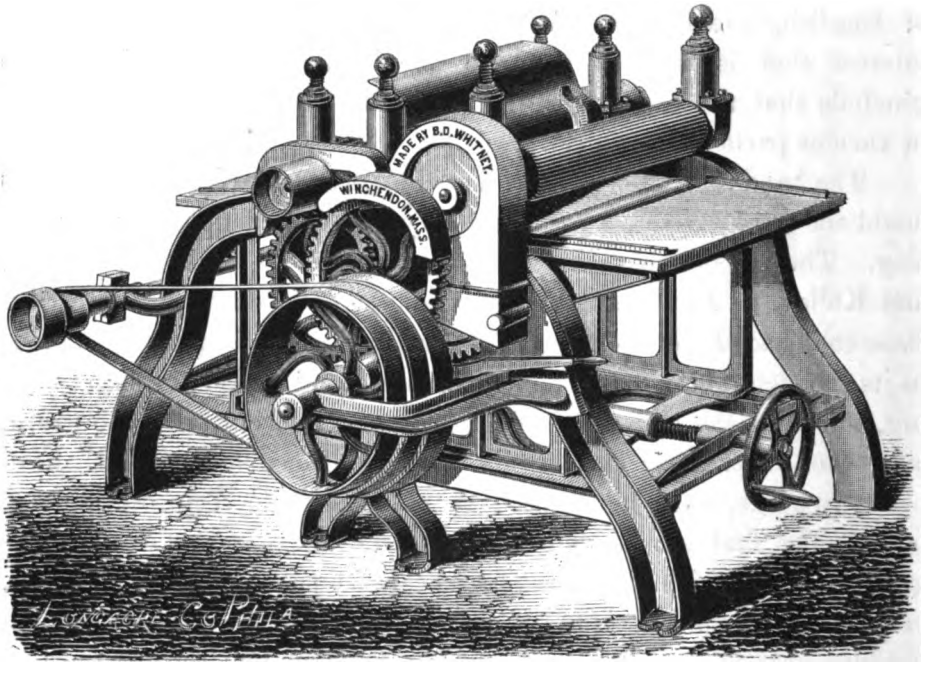
The illustrations comprise views of band-saw mills for log cutting of English, French, and American construction. From the great interest that is now everywhere felt in the matter it is safe to conclude that the capacity of the band saw will be thoroughly tested in various parts of the world.

The band-saw mills of J. J. Van Pelt, Esq., of New York, are no doubt the most extensive experiments yet ventured upon for log cutting. The sawing machinery was constructed by Richards, London, and Kelley, of Philadelphia, upon plans very much at variance with those that had theretofore been followed. The mill is quite anomalous in its character, being intended for cutting long timber for ship building, to follow the curvature of long timber, and cut with the grain, and other uses. The carriage is what is termed a "central" head block carriage, such as is used in our old style reciprocating-saw mills. The first cut is made by adjusting the log as the saw progresses, after which the slab face is carried past permanent gauges, very much on the principle of common hand slitting. The operation involves various devices for supporting, guiding, and setting the log, invented by Mr. Van Pelt, which are, however, of too special a character to have any interest here.

The blades used are from 55 to 60 feet long, 5 inches wide. The pulleys are 75 inches diameter, including hubs of wrought iron; they are covered with lagging of pine, over which is glued a covering of heavy harness leather. The bearings are for the wheel shafts 4 inches diameter, 12 inches long, made of six parts copper, one tin. The speed of the saw is about 4500 feet a minute, the tension from one to four tons. It may be mentioned as a fact of interest that the wheels first used were of cast iron, which were

PLATE LXV.

(PERSPECTIVE ELEVATION.)



PARALLEL PLANING MACHINE.

Intended for Thin Lumber, especially Hard Woods.—Planes one side; bed rests on inclined planes; has four geared feeding rollers.

B. D. WHITNEY, Winchendon, U.S.A.

in a few days crushed with the strain of the saw, and had to be replaced with wrought-iron wheels, a plan which the builders have since carried out in all their machines.

JIG SAWS.

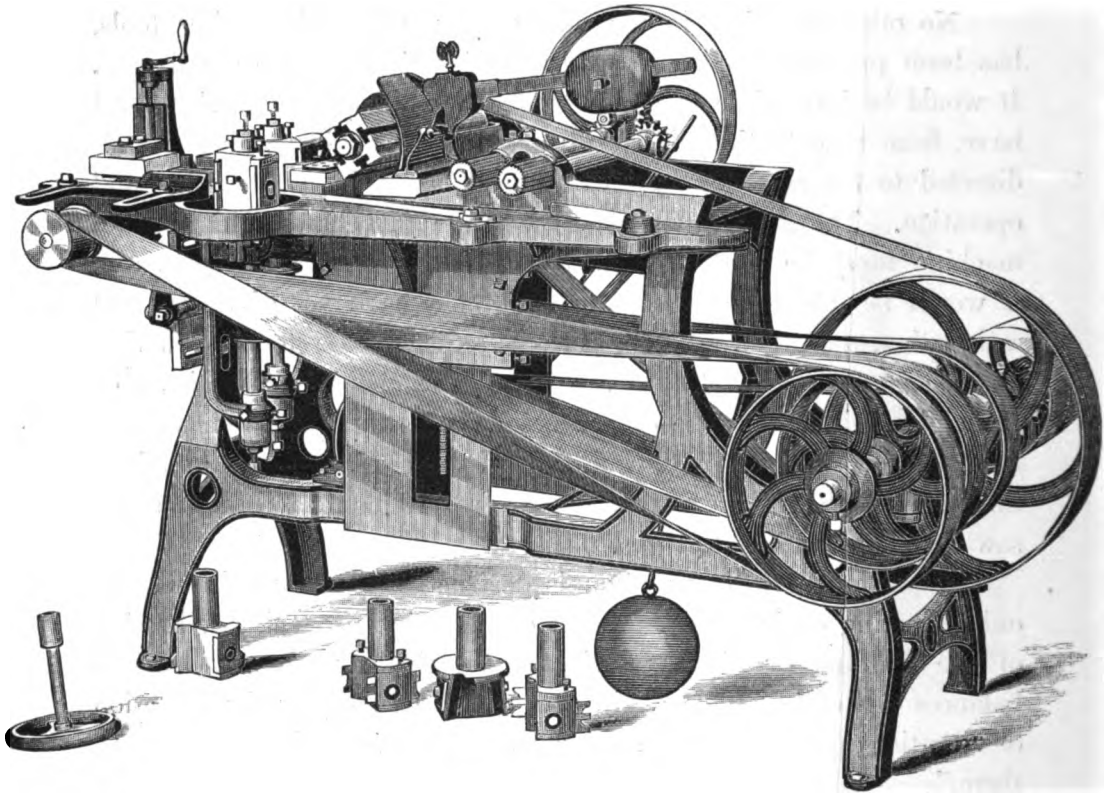
No other machine, in the whole range of wood-working tools, has been produced under so many modifications as the scroll saw. It would be impossible to define or describe the endless devices that have, from time to time, been introduced for working web saws, all directed to the same general end, but different in construction and operation. The many attempts to improve and change this form of machine must be ascribed to a *dissatisfaction with the results*, and it would be safe to say that none of them have yet given general satisfaction, and it would be, perhaps, equally safe to predict that *no machine ever will.* There are certain mechanical conditions, or principles, which must be observed in the construction of machines, in order to ensure wear, durability, and perfect operation; and it is impossible with our present knowledge of mechanics to build a scroll saw that will conform to these.

Rapid reciprocating motion is destructive to all machines, not only affecting their durability, but of necessity producing vibration of the framing or floors which furnish their support. Counter-balances are of but little avail, except as to changing the direction of vibration; and scroll saws, as a rule, "shake everything that is near them."

This objection, although insurmountable and quite serious, is not the only one met with in the construction and operation of scroll saws. The vibration produced by the reciprocating parts, is as their weight multiplied into their velocity. A high speed must be attained, and to reduce the weight is the only means left to counteract the evil. Hence, in making scroll-saw machines, the reciprocating parts and connections which should be the strongest parts, must, of necessity, be reduced to the smallest possible dimen-

PLATE LXVI.

(PERSPECTIVE ELEVATION.)



MOULDING MACHINE.

Adapted to Moulding Sash-bars, and general purposes.—Arranged with four spindles.

C. B. ROGERS & Co., New York, U.S.A.

sions, and become perishable for want of strength and wearing surface. Another difficulty that applies to these machines is, that for many kinds of work the sweep of the whole room, or at least a large space, is required to turn the work; this severs the machine into two parts, with independent connections at the ends of the saw, and as no coincident movement of the top and bottom guides is possible, except by positive connection, springs have to be used for straining. In all machines that have what is termed a "full sweep" for stuff this is unavoidable. The spring is limited in the speed of its movement, and irregular in tension; it may be regarded as a device of necessity rather than one of choice. These several difficulties, with which the inventors and manufacturers of scroll saws have to contend, furnish a sufficient explanation of the numerous attempts to produce machines free from some, or all of them.

The modern scroll saw can be classed into three general modifications: Saws strained by positive mechanism; Saws strained by springs; and unstrained Saws that are supported by anti-friction guides at their upper end above the work.

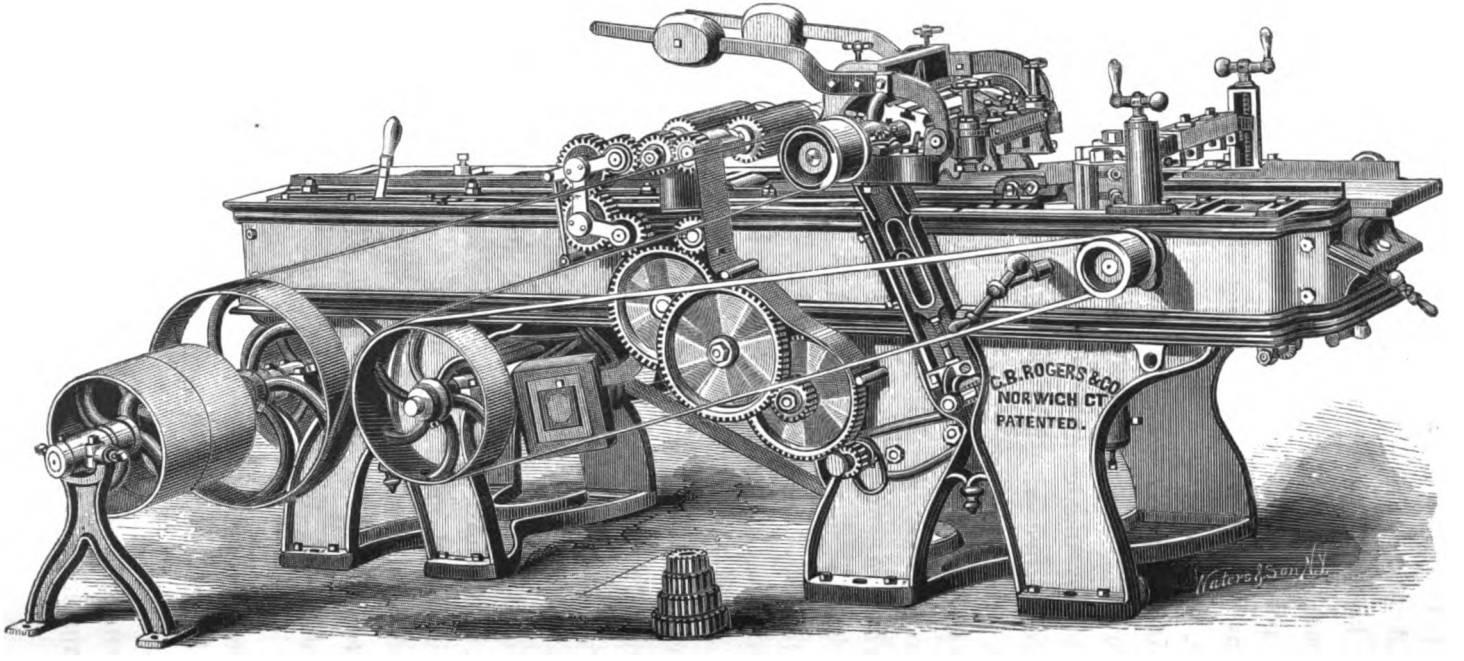
In the first class of machines, a reduced weight of the reciprocating parts is of great importance, whether we use a sash, levers, or flexible belt; this is the leading condition to be observed. The speed of the saw, in machines of this class, rarely exceeds 400 feet a minute, or 200 feet of cutting stroke, giving, of course, a slow performance; they, however, fill a place for deep cutting for inside or perforated work, but, in all cases, where the band saw can be used, these machines must be considered out of place.

Jig saws, strained by springs and having a clear open space for the stuff, are perhaps the most popular type. They have a greater range of adaptation; although not so speedy in heavy sawing, their claims for convenience quite balance this defect. The springs, if properly constructed and arranged, allow the saw to be held in open hooks at the end, so that it can be instantly removed for perforated work.

Tension springs for scroll saws, like other parts of this exceptional machine, have been applied under so many modifications,

PLATE LXVII.

(PERSPECTIVE ELEVATION.)



PLANING AND MOULDING MACHINE.

Arranged with five spindles.

C. B. ROGERS & Co., New York, U.S.A.

that a description in detail would be tedious and of no value. The principle involved is, however, directed, in a general way, to attaining the stroke with as little movement of the spring as possible; using a stiff spring, with a lever or other device to multiply its motion. The fact is the springs for tension used on scroll saws are subject to, and governed by, the same laws that prevent a durable construction of the machine proper. Stretching springs of india-rubber; compressive springs of india-rubber; coiled springs of steel; deflecting springs of steel and wood; in fact, springs of every kind have been tried. Stiff springs of ash wood, having a short movement, seem to have been for ten years past the most popular in America. The spring shown on the jig saw of F. Arbey, of Paris, among the illustrations, gives a good result, and has grown out of the abandonment of metal springs which were at first employed. Richards, London, and Kelley, Philadelphia, have recently introduced torsional springs for straining jig saws, a kind that present some very important advantages in the way of avoiding momentum. The springs consist of rods of cast steel, of square section, passing through fixed bearings at the ends, and carrying in the middle a short vibrating lever, which is connected with the saw.

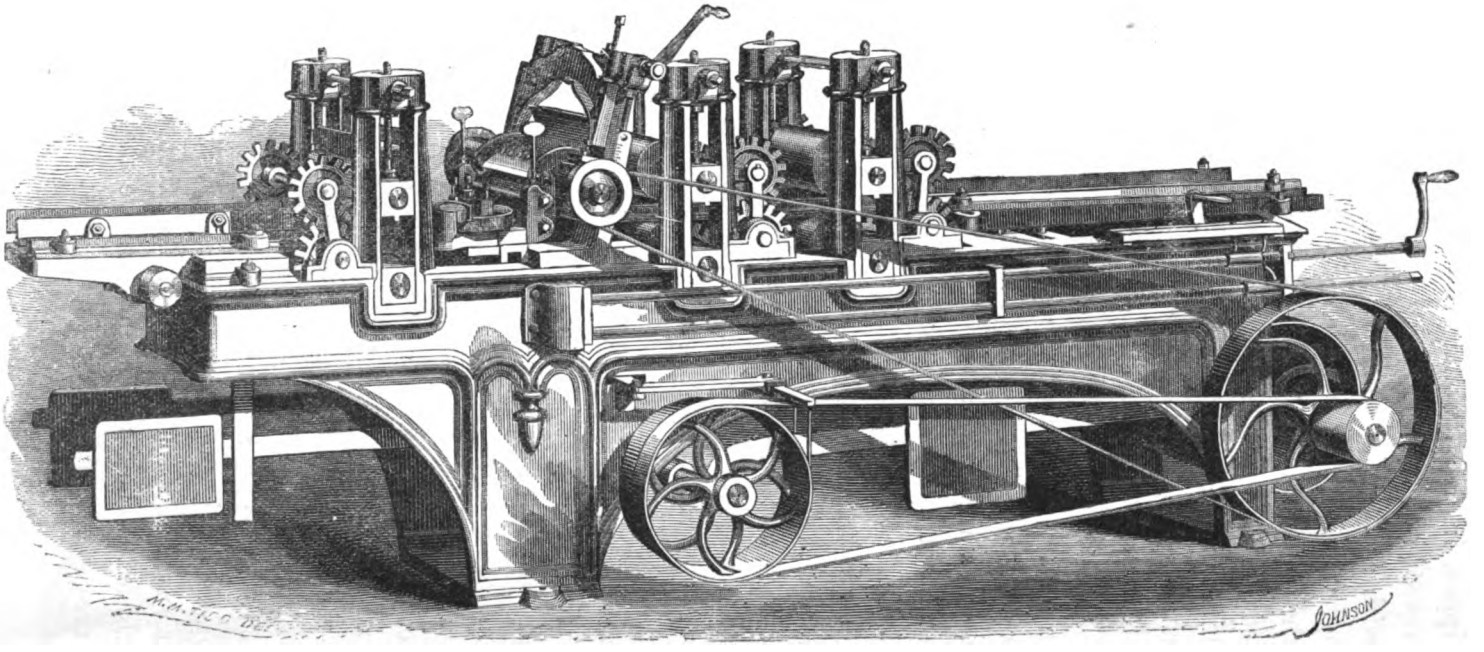
The unstrained web saw, supported in hardened steel guides, was introduced in America in 1865, under the writer's patents, and has, for some kinds of sawing, been quite successful; more than one thousand machines have since that time gone into use.

These machines were more especially adapted to the same class of work now done with band saws, and their importance has, with the introduction of this more rapid method of sawing, passed away. The stroke of the saws was from 2½ to 4 inches, the motion being very rapid; the crank shaft being run at from one thousand to sixteen hundred revolutions a minute.

It is to be hoped that changes in the style of wood ornamentation, or the substitution of rotary machinery, will in time take the place of jig saws, and that they may be exceptional among wood-cutting machines. Their use is now, as we may say, restricted to what is termed perforated work, in the best shops; and even this

PLATE LXVIII.

(PERSPECTIVE ELEVATION.)



PLANING MACHINE.

For General Purposes.—Arranged with three pairs of feeding rolls.

S. A. WOODS, Boston, U.S.A.

can in a great many cases be done with rotary tools, that not only do the perforating, and remove the interior wood, but smooth the surface at the same time. An illustration of this is found in the manufacture of saw handles and plane handles, in a large works in America where the "duplicating machine" with rotary cutters has been tested in competition with the jig saw and milling tools, the result being a saving of one-half in favour of the duplicating or tracing machines, which produced work of a better and more uniform character.

SLITTING AND CROSS-CUTTING SAWS.

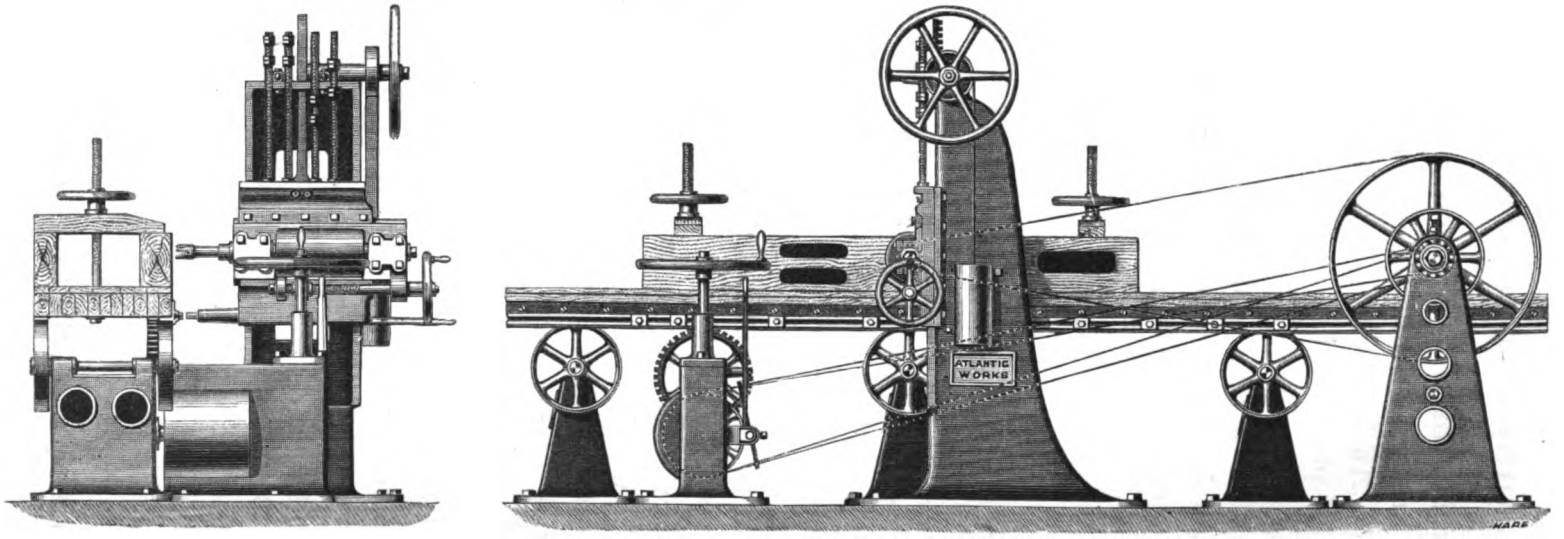
Saw benches, as they are termed, are as a machine so familiar that there can be perhaps but little of interest said about them.

The old stereotype saw bench has, however, in the last few years undergone many modifications, and its range of adaptation been increased beyond that of merely slitting straight lines, or, in other words, cutting out stuff to rough dimensions. The illustrations include benches with both cross-cut and slitting saws combined in one machine. Saw spindles with vertical adjustment for rebating, grooving, &c.,—saw spindles that are pivoted and are set to various angles for cutting bevels,—saw benches with two or more parallel saws for edging,—with various modifications of gauges, all of which are improvements upon the original sawing bench of twenty years ago. The bearings of saw spindles should be made of hard brass; the constant running and strain upon them calls for such material as will best resist wear. The belting for circular saws is as a rule too narrow, or upon pulleys of too small diameter. To drive a saw well, and without injurious strain upon the bearings, belts should be one-third the diameter of the saw in width, and the pulley equal in diameter to the width of the belt, which is a very simple rule, and does not give any more than the needed driving force, under fair conditions.

For cross-cutting saws, the nature of their work demands other

PLATE LXIX.

(TRUE ELEVATIONS.)



ROTARY MORTISING MACHINE.

For Boxing, Facing, Recessing, and Mortising. *Scale*—$\frac{1}{30}$th, $\frac{2}{5}$ inch = 1 foot.

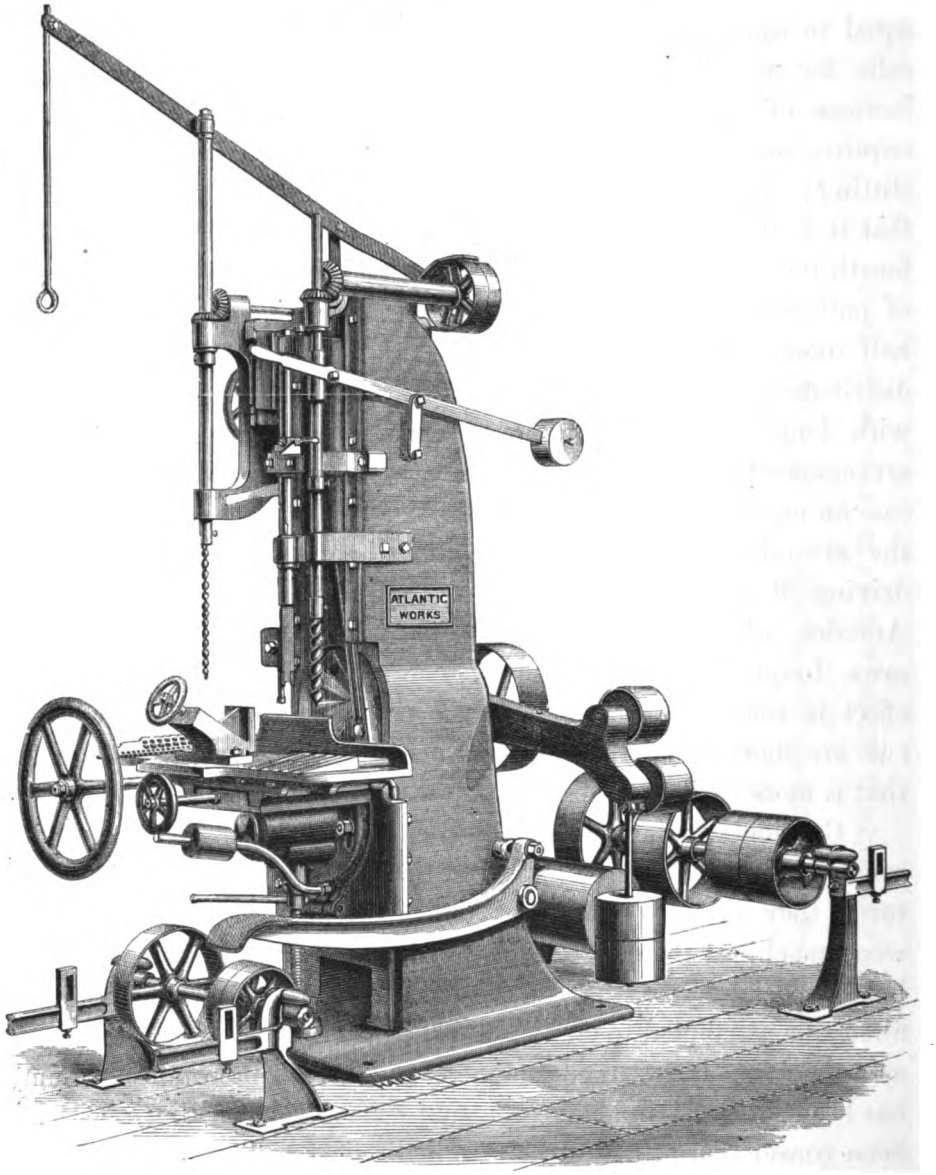
RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

proportions. The pulley must pass the material being cut, and represents a waste of the saw, or an imperative part of the saw, equal to some two and a half inches more than its diameter. This calls for a reduced diameter of the pulley, and a corresponding increase of face and width of belt. The nature of the work, too, requires more belting in proportion to the depth of the work than slitting; not that any more power is needed to do the cutting, but that it is done as a rule more abruptly and in shorter time. One-fourth the diameter of the saw is a better proportion for the diameter of pulleys on cross-cutting spindles. Their faces can be one and a half diameter in length. The use of fly-wheels to store up and distribute power for cross-cutting saws, which are sometimes used, with long mandrils to remove them away from the work, is an arrangement that cannot be recommended, and will be found in every case an expedient to make up a want of belt power. The objection is the straining of the saw plate, and the danger of injuring it by driving it as it were by impact. Such wheels are used only in America, where they are applied both to cross-cutting and ripping saws, frequently, although not generally, and no doubt with good effect in some cases, where the belt power is deficient and when the cuts are short and irregular; but it is the wrong remedy for a fault that is more easily corrected by increasing the belting.

Considering the general use of circular saws in America, and the great number that are employed in the vast interest of wood manufactures, they may be safely set down as the most imperfect of all wood machines there in use, not only in their general construction, but in special errors, that seem to have lasted so long that they may almost be attributed to stupidity. The ordinary American saw bench, as a machine, is regarded as one of no great importance. Lumber has been so cheap and plentiful, that economy in cutting out has not been considered, attention being all directed to tools for shaping and finishing, or, in other words, the economy of labour has been the ruling object, while the economy of material, a secondary matter. Hence we find all the machinery for cutting-out inferior to that made and used in England and on the Continent.

PLATE LXX.

(PERSPECTIVE ELEVATION.)



RECIPROCATING MORTISING MACHINE.

With boring spindle and auxiliary boring attachment for joint bolt-holes.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

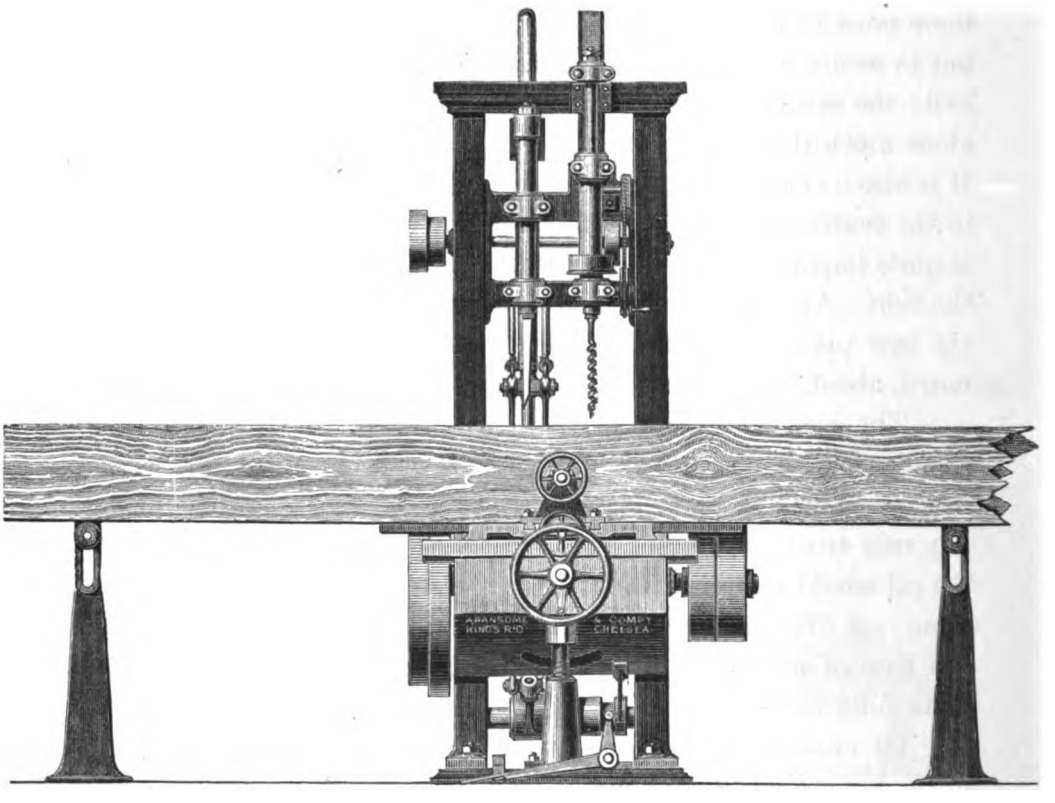
In noting some of these errors in saw benches, we will first direct attention to gauges for guiding the lumber. Leaving out the usual crude means we find for adjusting them, they are as a rule a long strip or fence passing *behind* as well as in front of the saw, and as it is impossible to press the lumber against the teeth at the *back* of the saw, such gauges are not set parallel with the plate, but at an angle with it; the result being that true lines cannot be cut, and there must be an allowance for future dressing, not to smooth alone, but to secure dimensions. The waste of material is, however, but one evil: the saws never work well, and have to be used for this reason alone much thicker than would be necessary if the gauges were right. It is also a common thing in America to find a saw spindle mounted in the centre of a table, eight to ten feet long, in a position where it is quite impossible for the operator to work it, except by standing at the side. As a rule, no packing boxes are used to steady and lubricate the saw plate, which for this and other reasons must be, as before noted, about twice the thickness of a first-class English bench.

The bearings are usually made on a plan termed self-oiling, though for what reason is hard to tell. The operator is continually in charge, has to inspect and watch the bearings, and would not in any case trust the fibrous packing for an interval much longer than the oil would remain without it; besides, as a rule, there is about the same or a greater amount of oil used and applied nearly as often as in the case of an ordinary bearing. This matter has, however, been more fully noticed before.

Of cross-cutting machines the illustrations present some good examples. They can be divided into two classes; those wherein the saw is moved and the lumber stationary, and those that have fixed saws with moving carriages for the lumber. The operation in fact involves the old proposition of moving tools or moving material, a general principle that runs through all operations in wood and metal work. For light material and small prices, the cross-cutting machines with fixed saw and carriage are generally used. On the contrary, for heavy stuff the saw is moved. The swing saw, or radius saw, is the most common type in America, because of its cheapness and overhead

PLATE LXXI.

(TRUE FRONT ELEVATION.)



RECIPROCATING MORTISING MACHINE.

Of 7 inches stroke, with boring spindle. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

attachments. Various modifications, however, are met with, most of which have peculiar adaptation to special purposes.

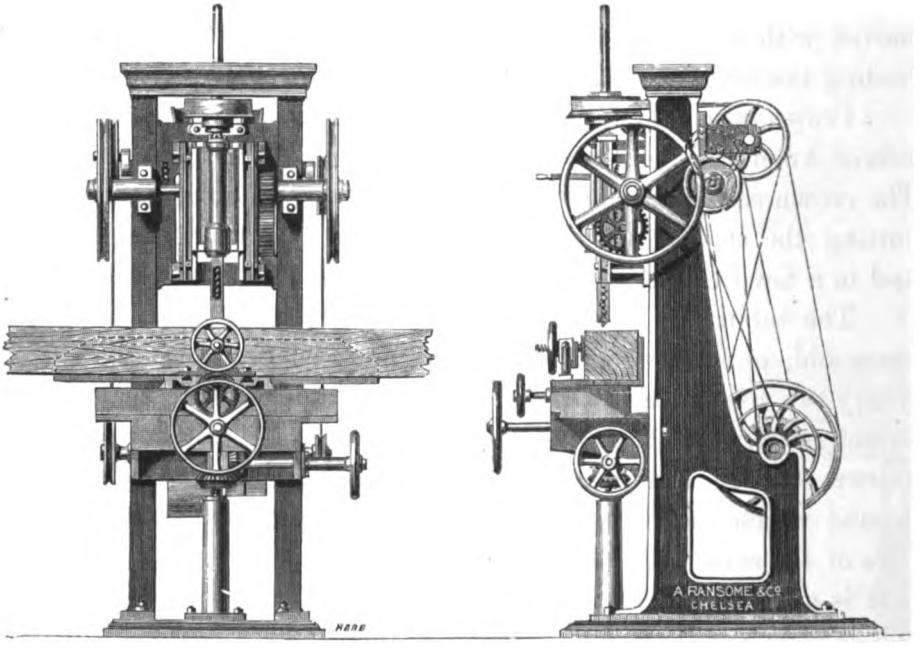
In the large carriage cutting-off saw illustrated, there is a peculiar device for keeping the carriage square that deserves some notice. There is on each end rail a rack, working in two pinions, keyed to a parallel shaft passing beneath the table, which makes the movement of the two ends coincident and positive, independent of the track or bearings that carry the table. By this device the carriages of such machines can be mounted on rollers, instead of sliding guides, and be moved with but little effort, which is in tenoning and other hand-feeding machines a matter of the greatest importance.

Crown saws and tubular or cylinder saws are so little used, outside of America at least, that they can be regarded as special machines. The crown saw has, in the Eastern States, been adopted generally for cutting the staves for wooden vessels and other concentric pieces; and in a few instances for the naves of wheels and slots for chairs.

The tubular or cylinder saw is an American invention, some ten years old, and is without doubt the most novel application of the rotary saw ever attempted. As the machine has been covered with patent restrictions thus far, and but few are in use, it is not popularly known even in America. It consists of a tubular shaft or cylinder, around which the belt passes supported in semicircular or half-bearings of the same diameter: to the end is attached a short crown saw that is as much larger than the cylinder as will clear the belt. The belt is wide, very thin, and uniform in thickness. The wood is carried over this saw by means of a carriage, the saw cutting out a semicircular core, the belt *running in the kerf* and passing through with *the* saw. It is intended for making cylindrical wooden pipes, or more especially eave troughs and conductors for the roofs of buildings. By using saws of varying diameters, which are quickly changed, concentric semicircular pieces are cut from a piece, leaving but little waste; the edges being matched or tongued and grooved, two pieces when laid together make a symmetrical and water-tight wooden pipe, which if well coated inside with pitch and painted on the outside, lasts for many years; much longer than sheet-metal

PLATE LXXII.

(TRUE ELEVATIONS.)



MORTISING MACHINE.

Adapted for Hard Wood.—Arranged with hollow piercing chisels.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

conductors for vertical leads, while the horizontal troughs will last many times as long.

A vibrating saw with a curved blade, that formed a segment of a cylinder, was some years since patented in England, but does not seem to have come into use; its purpose was no doubt the same as that of the tubular saw described.

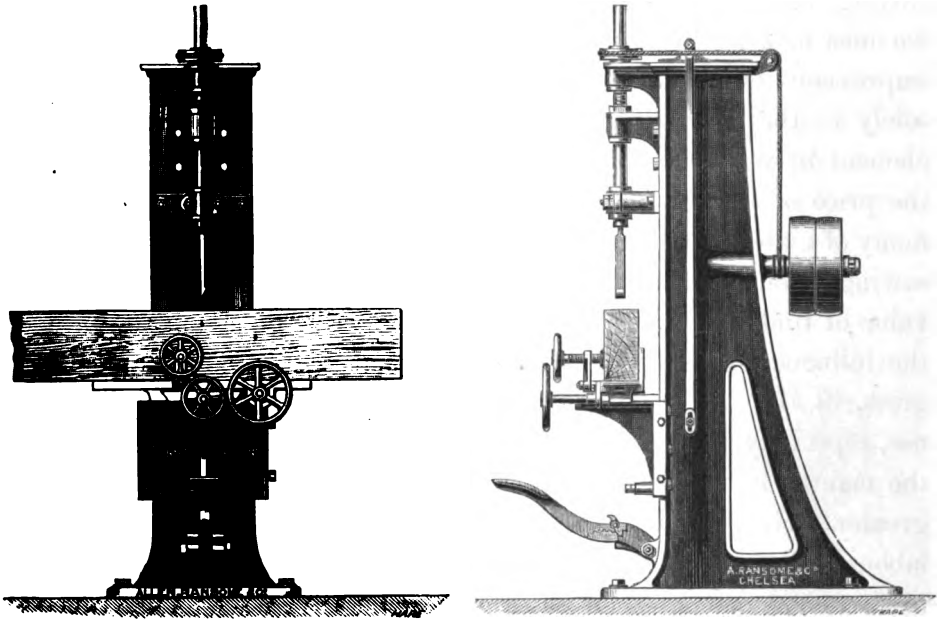
We will close these remarks on saws with saying that the first, and indeed the most important, of all manipulations in wood work is cutting out and dividing it with saws, and that to their improvement we must look for a greater economy in material. As remarked already, improvements in sawing machinery in America have been directed solely to the saving of labour, which is or has been the expensive element in wood manufactures; but so rapidly as not to be realized, the price of lumber has risen to a point that demands a greater economy of material, and this is mainly to be effected by improvements in sawing machinery and in the plans of traffic. In Europe, where the value of timber has been greater and the value of labour less, we see the influence of those inevitable laws that regulate mechanical progress, in the vastly better machinery for sawing which is there in use, especially for re-sawing and cutting out stuff. We also see it in the manner of traffic, in lumber, and in various ways that point to a greater saving of material, and, as might be assumed, to a saving of labour at the same time; for what may be lost by a larger investment in first-class machines for sawing, is generally saved many times in the planing, and after dressing, as well as in the power needed to operate the machines.

CUTTING AND CUTTERS.

The following remarks on cutting, or the operation of edges, should for some reasons have preceded what has been said about saws; but as the general idea conveyed by the term "cutter," as well as cutting machines, seems to more especially apply to operations other

PLATE LXXIII.

(TRUE ELEVATIONS.)



RECIPROCATING MORTISING MACHINE.

Intended for Soft Wood, and to run at High Speed.—With automatic chisel reversing device. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

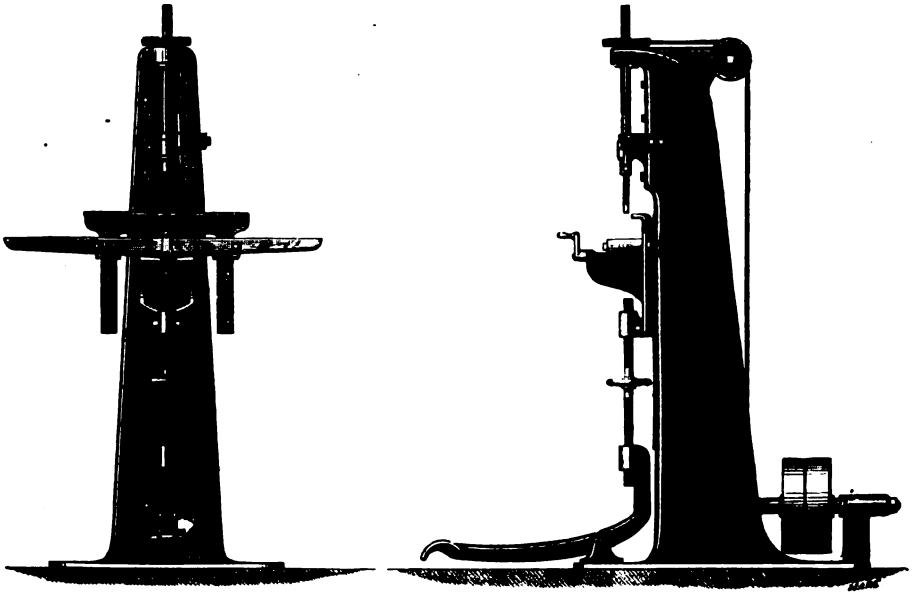
than sawing, it is inserted at the beginning of the matter devoted to machines that operate upon the surface of material, and as a rule have detachable cutters.

The general name of "wood cutting," as applied to machines for working wood, at first seems incorrect, for the reason that it is compared in the mind with "metal cutting," as applied to those for working metal. There is, however, aside from the difference of material, a great distinction, which makes the term especially applicable to all machines for working wood, and restricts it to a class only of those for working metal. Metal is shaped by melting and moulding, and by forging, or as we will say by the influence of heat; it is also shaped by abrasion or grinding, as well as by cutting, while all operations in wood work are simply cutting. The material must in all cases represent in its outline, dimensions that will cover the finished form; it cannot be moulded, bent, nor compressed into shape, we can only cut away the surplus, and leave the finished form. Here then is a grand distinction from the manipulations of other material, and it is quite interesting to follow out the various operations in wood work, which are more diversified than those of almost any other branch of industry, and find them all resolve themselves into simple cutting. The wedge, that grand ally of man, that enables him to mould the materials of nature to his purpose, is supreme in wood work; cutting edges can be regarded as wedges for splitting off or wedging off the surplus material, giving true dimensions by removing that which lies beyond the lines.

Leaving out reciprocating saws and reciprocating mortising machines, all popular wood machines now in use operate upon one principle of rotating cutters; circular saws being identical in their operation with planing tools, there being in fact no exception. To generalize further, all operations can be divided into two classes, one in which the cutting edges are parallel to the axes of rotation, the other in which they are transverse to the axes of motion; to the first class belong circular saws, cylinder planing machines, moulding machines, &c. The second comprises traversing planers, boring and routing tools.

PLATE LXXIV.

(TRUE ELEVATIONS.)



RECIPROCATING MORTISING MACHINE.

For Joiners' Work, to run at High Speed.—Has power reversing devices.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.;
AND
ALLEN RANSOME & Co., London, England.

Cutting wood consists of two distinct operations—*cross-severing the fibre*, and *splitting the fibre parallel with its lamination.* The two are of course always combined; for to remove wood they must both be performed: yet to go intelligently about the construction of cutters and machines as well, this fact must never be lost sight of.

The greatest amount of power and the best edges are needed for cross-cutting the fibre. To illustrate by a familiar example, to cross-cut a log 12 inches in diameter requires some time and a considerable amount of manual effort, while a single blow may split it into halves after cross-cutting.

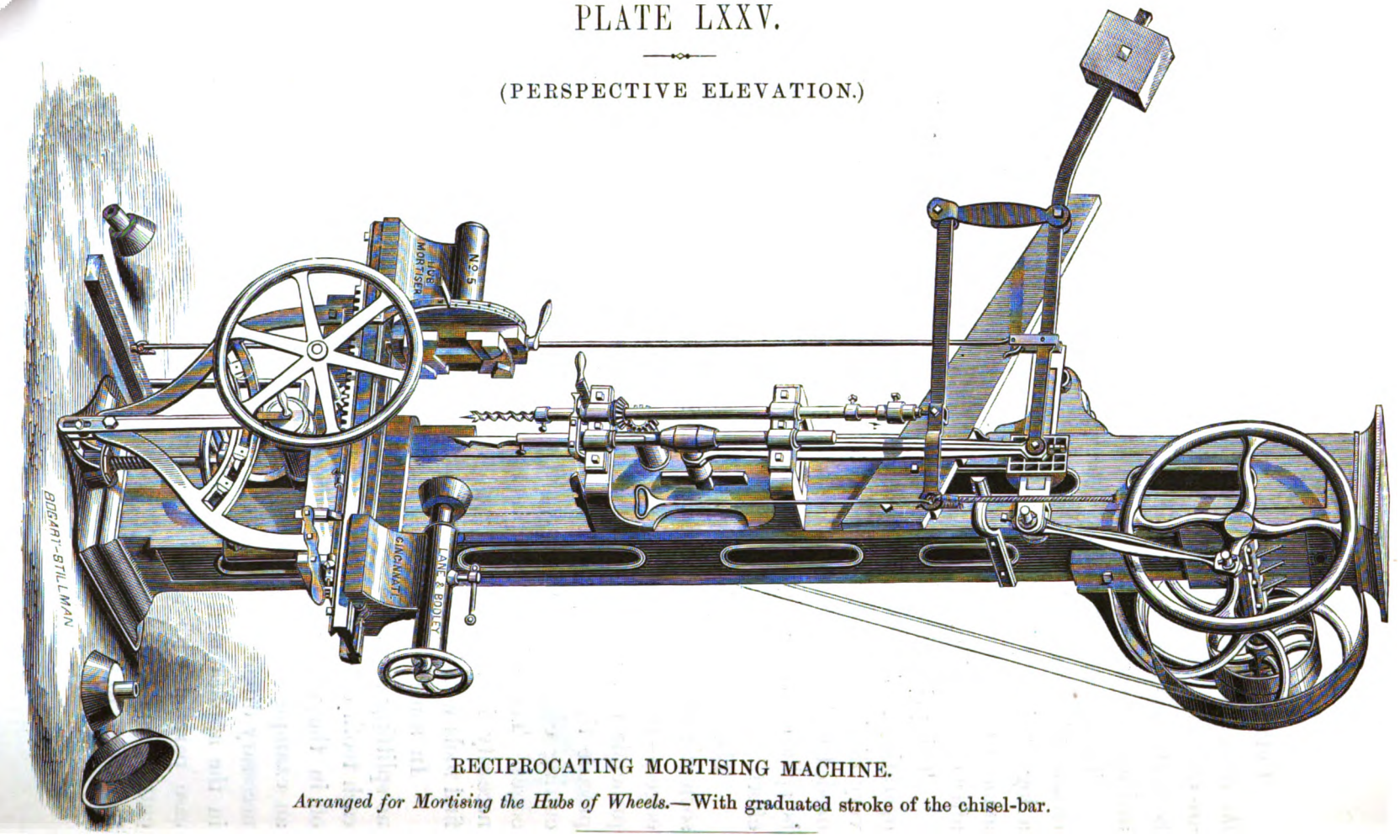
This principle exists throughout, and with the same relations in all operations. An auger is another example in an operation apparently very dissimilar to the one cited, yet just the same. The power is needed mainly to cross-cut the fibre with the spores, while the wood is split off and raised from the bottom of the hole without much effort.

The spores require frequent sharping—must have thin edges, and soon wear away; while the opposite is true of the radial or splitting edges,—they can be blunt, or even dull, and wear but little. Another principle to be observed is that the cross-severing of the fibre must precede the splitting process; to apply it to cutting tools the cross-cutting edges must act *first*, and must *project beyond* the splitting edges. There is no exception to this rule, which is from sheer necessity in most cases carried out, yet it is not unfrequent to find tools working on the contrary principle.

In some cases the wood is cross-cut at such short intervals that no splitting edges are needed; the slitting saw is an example of this: each tooth cuts off its shaving transverse to the fibre, which is split off in the very act of cross-cutting. The cross-cutting saw is also an example of the same kind, although apparently different. The necessary difference in the form of the teeth arises from the difference in the application; the rotation of the saw plate being in the one case parallel with and in the other transverse to the fibre. The cutting edges must, in both cases, bear the same relation to and be transverse to the fibre—parallel to the plate in the cross-cutting saw,

PLATE LXXV.

(PERSPECTIVE ELEVATION.)



RECIPROCATING MORTISING MACHINE.

Arranged for Mortising the Hubs of Wheels.—With graduated stroke of the chisel-bar.

LANE & BODLEY, Cincinnati, U.S.A.

and transversely in the slitting saw. Here then we find the theory of cutting edges for wood resolved into a most simple matter, which can be stated in a few propositions, as follows :—

1st. Wood cutting consists in two operations, cross-cutting and splitting.

2nd. Tools for cutting wood must have edges directed to each of these operations, except it be cross-cut at very short intervals, as in the case of saws.

3rd. The cross-cutting edges must act first, and project beyond the splitting edges.

4th. Cross-cutting edges if applied at an angle with the fibre, will act with less power, and be more durable than if at right angles with it.

5th. Splitting edges act best when parallel to the fibre, but at an angle to the direction of their movement.

6th. Cutters for perforating, or "end tools" of all kinds, should be so arranged that their action is balanced across the centre of rotation.

Keeping these general propositions in view, there need be in no case any trouble in determining the form and proper application of cutters.

The same general rules apply throughout; as has been stated all operations are cutting, so it can be said that all cutters are the same; whether the teeth of saws, the edges of angles, the cutters of planing machines, or turners' tools, their operation is identical.

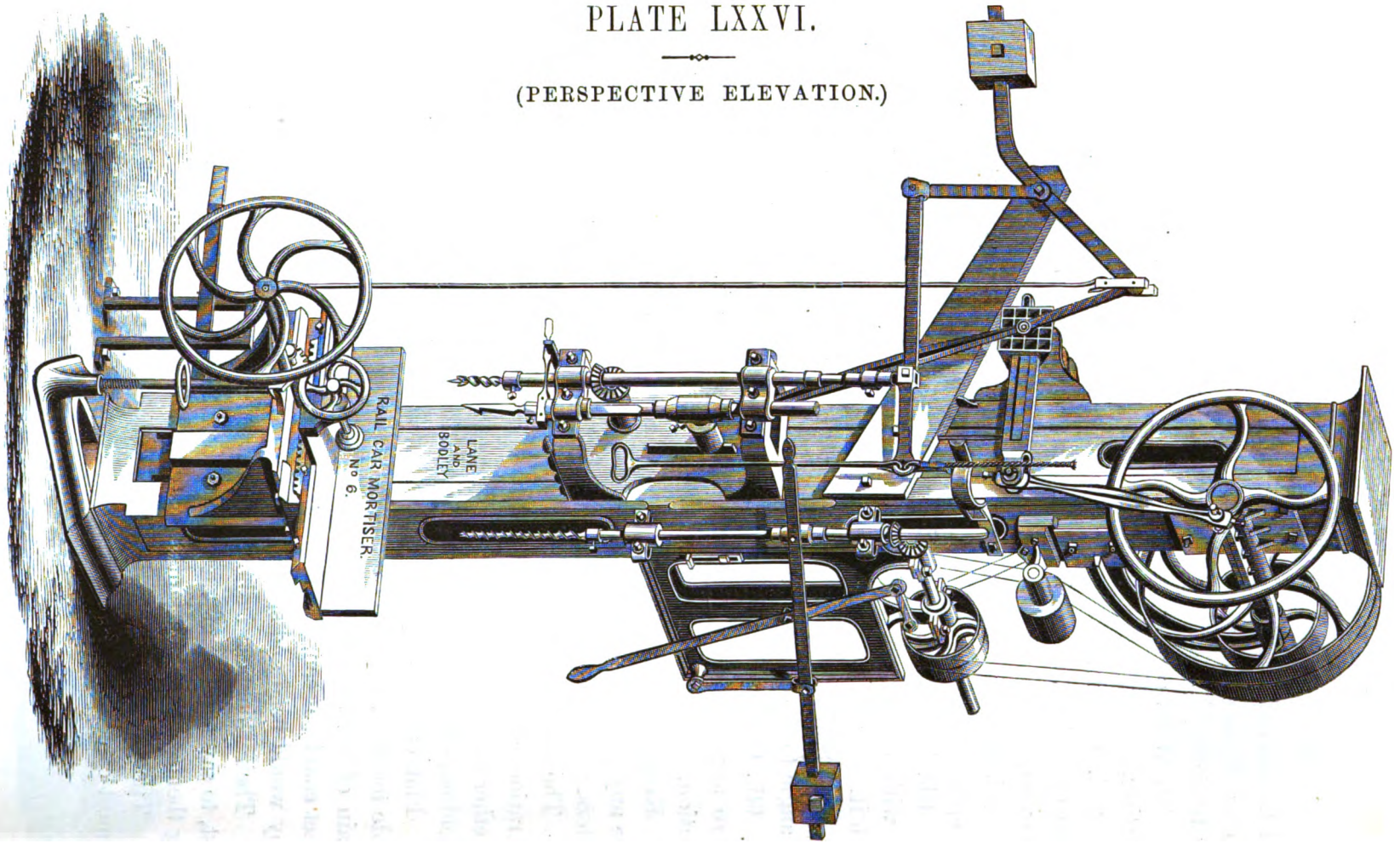
Flat cutters for planing and moulding machines are as a rule made too thin, especially those for mouldings of deep profile. If the strain of the work were to fall on them in a state of rest when the effect could be seen, we should be astonished at the manner in which they would bend and spring.

Their thickness is, however, a very important element in their cost, to say nothing of the increased expense of dressing or sharpening them, and the constant tendency is to make them thin.

The necessary strength can be obtained with cops, or back plates, in most cases; and quite a reform has sprung up in the last few years

PLATE LXXVI.

(PERSPECTIVE ELEVATION.)



RECIPROCATING MORTISING MACHINE.

Arranged for Rectangular Framing.—With auxiliary boring spindle and graduated stroke of the chisel-bar. (Over 1500 machines in use.)

LANE & BODLEY, Cincinnati, U.S.A.

in the use of heavy cops, on planing and moulding machines. The acute angle which most makers have tried to obtain for cutters, has interfered with this for the want of clearance for cops and bolt heads. There is no question but that this plan has been carried to an extreme, and that the low angle aimed at has in most cases been wrong, especially for hard wood. In America cutters of solid steel, of from 12 to 16 gauge, are now extensively used on planing machines manufactured from sheet-steel by saw makers; they cost much less than the thick cutters, and when properly mounted give as good or better results. In making flooring, the rule is to have the cutters soft enough to be filed, in which way they can be dressed in a short time without being removed from the cylinders. Edges will not of course at this temper last so long, nor do such smooth work, but the gain in sharpening is enough to compensate for this in the case of working flooring boards, which need not be so smooth as most other kinds of planed timber.

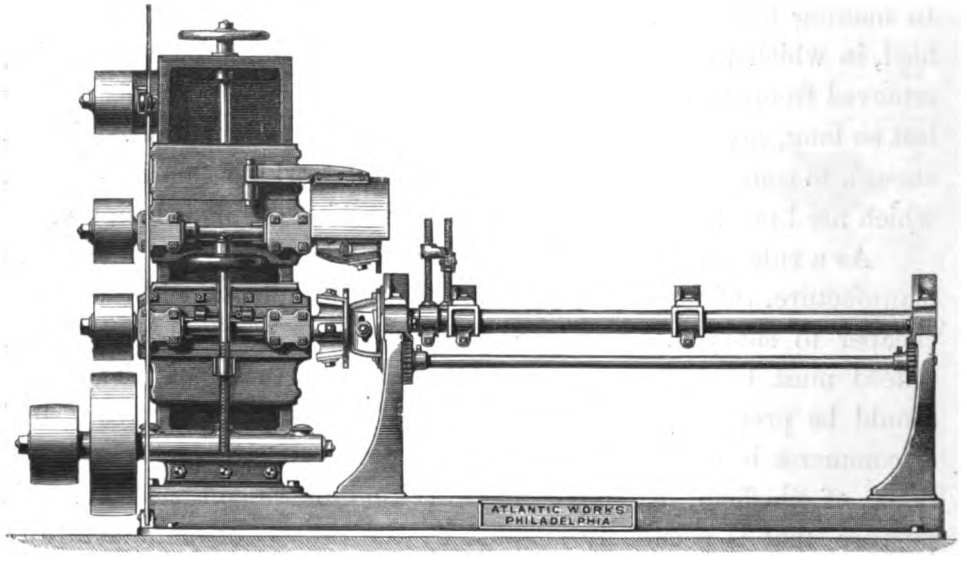
As a rule cutters should be of iron, steel-laid; they are cheaper to manufacture, safer from danger, and if thinly plated with steel are cheaper to sharpen. The iron used should be of the best quality, indeed must be, to secure the welds in laying the steel. The steel should be prepared for the purpose, as the ordinary sheet cast steel of commerce is not at all suited to the purpose. Messrs. Jessop and Sons, of Sheffield, England, make a kind of ribbon steel for this purpose, that is peculiarly adapted by the process of manufacture in which it is what a smith would call hammer refined, and can be laid by pressure, or rolling, retaining its integrity of fibre, without the hammering-off process needed in working the ordinary cast steel of commerce.

The helical cutters of M. Arbey, illustrated in the plates, are quite a novelty, and have given a good result so far as the system has been applied, which in his works at this time is quite general, for plane cutting at least. The machinery for preparing the cylinders is special, and complicated, and much credit is due to the enterprise that has incurred the expense and risk of such tools for the improvement of wood machinery.

The plan of sharpening the cutters with vulcanite emery wheels,

PLATE LXXVII.

(TRUE ELEVATION.)



TENONING MACHINE.

For Single Tenons.—Carriage mounted on rollers; squared by a geared shaft; range to 12 inches. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

mounted on and forming an integral part of the machine, is one that is not only peculiarly adapted to his system of helical cutters, but could with great advantage be used for the ordinary straight ones, dispensing with the skill needed in grinding, and the trouble of removing and adjusting them. Cutters of cast iron with chilled edges have been to some extent used in moulding machines in America, with what success and for what object we have no information that warrants a further notice of them here.

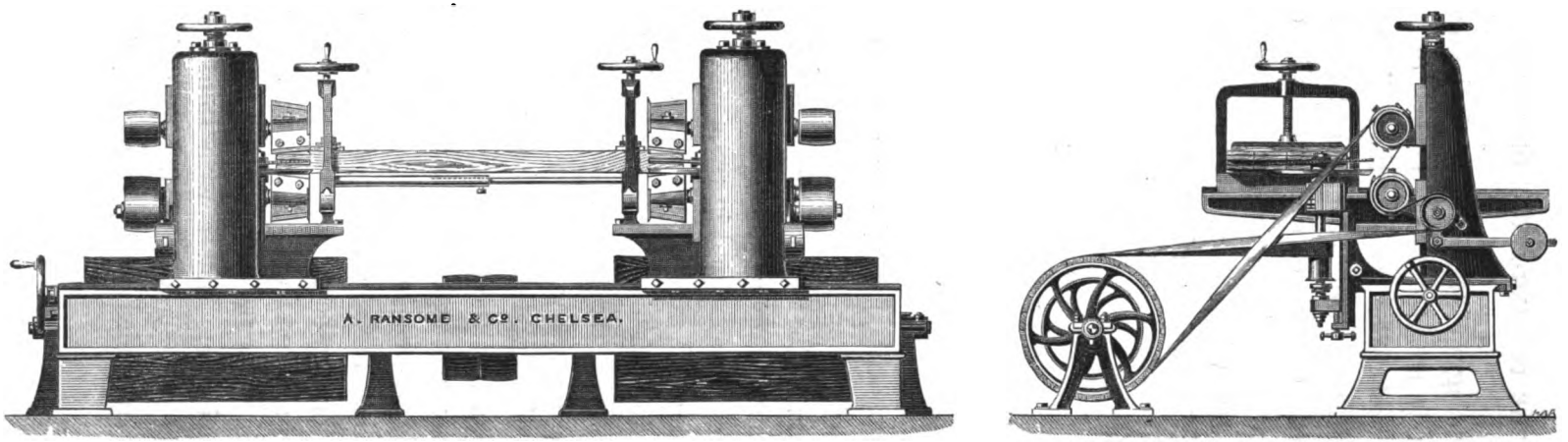
THE CUTTING-ANGLE OF EDGES.

In the brief remarks that will be offered on this subject, the writer is conscious of assuming propositions very much at variance with popular opinion. The deductions are not, however, based upon theoretical conclusions, but upon a long series of experiments, extending over a period of twenty years, and in the application of wood-cutters to every variety of wood, and for nearly every kind of operation known, such as turning, planing, scraping, boring, paring, &c.

The angles at which the faces of cutters are set, and their consequent bevel at the edge, is a matter which has not received much consideration from the builders of wood machines generally, who assume, it would seem, that the prime object is to get a low angle and a thin edge, in other words, to cut instead of scrape. That this is wrong can be easily proved by citing the many cases in which from necessity the plan has to be abandoned for the obtuse edge. The coped plane iron, the scraper, and blunt tools generally attest the fact that there are conditions in wood cutting that require something different from a thin or acute edge. That a given amount of wood can be cut away with less power with thin than blunt edges is evident, provided the edges have the same conditions, but there is the point; the power is expended merely in *severing* the fibre, and not in

PLATE LXXVIII.

(TRUE ELEVATIONS.)



DOUBLE TENONING MACHINE.

For Tenoning both ends of Framing at one operation. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

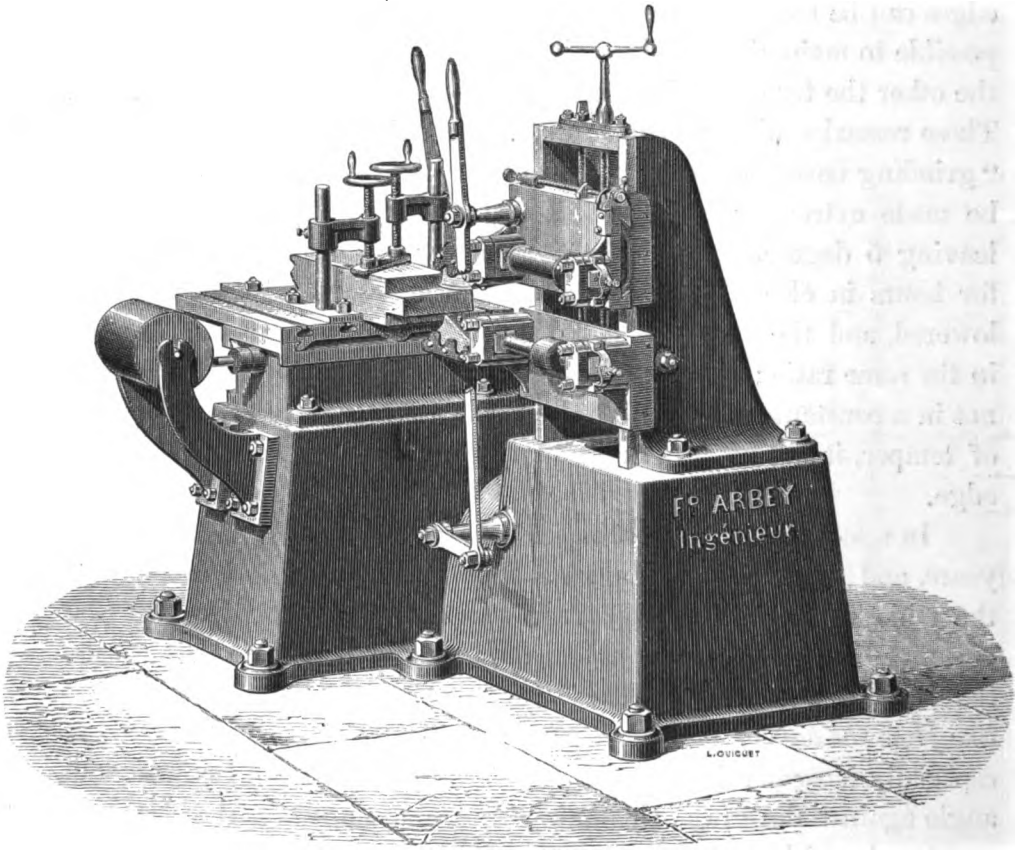
splitting of wood after the fibre is severed, for this first object we need an edge that is sharp. Its angle, whether acute or obtuse, is a secondary matter that relates to splitting off the wood; but a sharp edge is the great desideratum. Now a sharp edge cannot be at the same time a *thin* one, and stand; it is not in the nature of things possible; thin edges must be soft or they will break; thick or blunt edges can be hard, because they will not break. In the one case it is possible to maintain for a long time a sharp edge to sever the fibre, in the other the true edge is at once destroyed, as soon as set to work. These remarks relate of course to the immediate edge, and not to the "grinding bevel" of cutters. A cutter with a bevel of 45 degrees can be made extremely hard, and, if set at say 50 degrees on its bed, leaving 5 degrees for a "whetting bevel" and clearance, will work for hours in clean lumber and maintain its edge. As the angle is lowered, and the edge becomes thinner, the temper must be reduced in the same ratio; the effect, however, on the capacity of the knife is not in a constant ratio, for as soon as it has reached a certain degree of temper, it has no further property of maintaining a sharp cutting edge.

In a long series of experiments, extending over a period of many years, and in the case of many machines, it has been demonstrated in the Ohio Tool Company's Works at Colombus, Ohio, U.S., that for working boxwood, rosewood, banyan, cocoa, and similar hard woods, the best angle for the cutters is to set their faces almost *on a radial line from the axis of the spindle*, and in some cases, when the wood is especially irregular in grain, or is (as is often the case) cut at a low angle against the grain, this unusually obtuse angle for the cutters is not found sufficient, and they are so set that their faces meet the wood with a "dragging cut," in other words, at an angle more obtuse than a right angle.

That this statement is an extraordinary one and greatly at variance with usual practice, the writer is fully aware, and if it was not founded, as before said, upon what might be termed "exhaustive experiments," that have now lasted for fifteen years, he would question the propriety of laying it down as a rule for wood-cutting machines.

PLATE LXXIX.

(PERSPECTIVE ELEVATION.)



TENONING MACHINE.

For Joiners' Work and General Purposes.—Arranged with helical cutters.

F. ARBEY, Paris, France.

It might also be a matter of interest to follow out some of the facts in the history of this unusual application of wood cutters.

The Ohio Tool Company are manufacturers of mechanics' hand tools, especially of such tools as are in part of wood; planes being a specialty of which they make more than three hundred thousand each year. All operations, even to mortising the throats, are performed by machinery. Their machines for moulding and planing are of every conceivable arrangement and capacity, from the surface planer of two feet in width to the milling cutter three-eighths of an inch in diameter, consisting of not less than forty independent machines, operating with rotary cutters. Throughout this whole range of machines is carried the system of obtuse cutters, not only for the working of such hard woods as have been named, but the native wood of the country, which is only of a medium hardness, such as beech, maple, and hickory wood; and even in some instances soft pine has been successfully worked in the same machines; and, what is even more strange, wood that is perfectly green, and unseasoned.

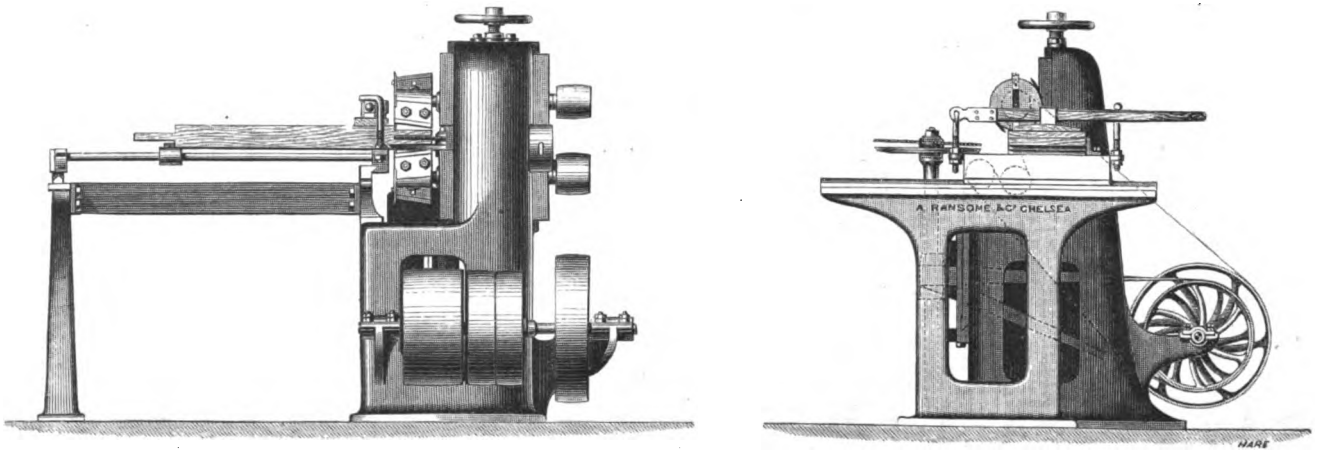
The experiments were first suggested to Mr. Montgomery, the master mechanic, from his experience in the manufacture of what are known as veneer planes, in which the iron is set more vertical than in other planes. To determine a proper limit to this he had made a number of planes at various angles, and found that, as the iron assumed a position more at right angles with the surface of the wood, a better result was obtained, and that the caps became unnecessary. He conceived the idea of applying the same principle to the rotary tools, and constructed first a machine for moulding "Howel planes," used in coopering. This machine had radial cutters, their faces being on a plane passing through the centre of the spindle; and to the astonishment of all, the Howel boards and blocks were moulded perfectly true and smooth, *without any reference to the grain of the wood.*

This of course led to further experiments, ending in the system described.

A great gain, aside from doing that which had been thought impracticable before, was in dispensing with the caps on the cutters of all the machines; and, secondly, in the cutters being made to a

PLATE LXXX.

(TRUE ELEVATIONS.)



TENONING MACHINE.

For Joiners' Work.—With copying, or scribing, spindle. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

true profile of the moulding wanted. Two things that so simplified the machine operations in their extensive works, that special machine hands were no longer needed, and the plane makers themselves performed the power work needed on their planes, each in his turn using the machines, which became a kind of common shop property, about which there was no mystery, and to operate which no special skill or knowledge was required.

These facts are alluded to in detail here for the reason that they present a kind of anomaly in wood work, and as they cannot fail to have an interest because of their novelty.

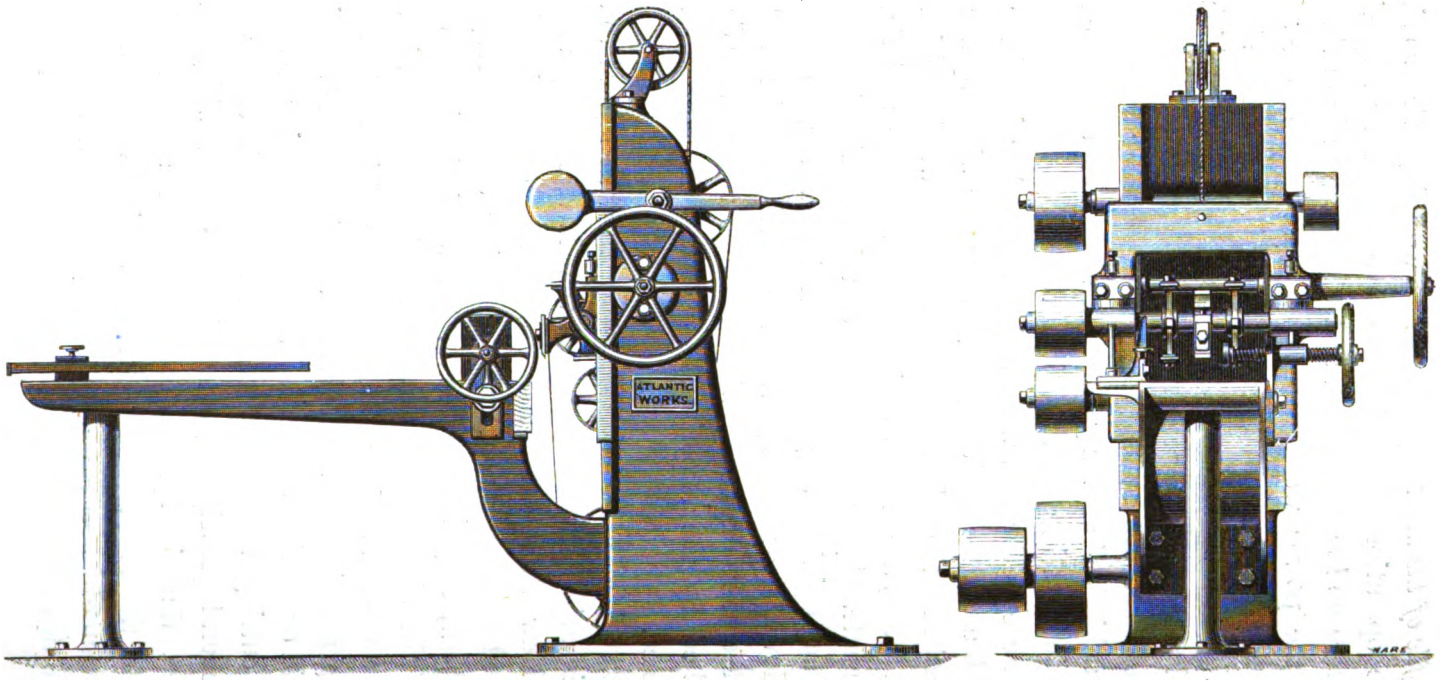
These experiments, with which the author has been personally identified, and others of an analogous nature with popular wood tools, have confirmed the opinion that the cutters of wood machines, especially for hard wood, are set too oblique to the surface, and that the bevels are too acute. The present state of this branch of manufacture, and the present opinions as generally held, however, do not warrant his laying down diagrams to govern the practice of others. The general idea is therefore suggested with the hope that further data will soon be reached by the experiments of others in a matter of so much importance.

That a kind of reaction is setting in with regard to the angle of cutters is evident from some facts that have recently come to notice. About New York city the manufacturers of flooring boards have discovered that by turning the matching cutters *wrong side out*, or *upside down*, they worked better. Now this is simply changing the angle of the edge, substituting the bevel for the face, in other words, setting the cutters in a more radial position. The friezing or moulding machine, now extensively used in France and in America, with solid or milling cutters, is but another step in the same direction.

In cutting brass and iron the analogy is quite complete, the same general principles govern in each case, with, however, this difference, that in metal work experience and necessity at once determine the proper angle for the cutting edges, which in wood cutting cannot be so readily observed, and is a much more obscure matter to determine.

PLATE LXXXI.

(TRUE SIDE ELEVATIONS.)



TENONING MACHINE.

For Multiple Tenons.—With fixed bed and movable cutter-heads. *Scale*—$\frac{1}{20}$th, $\frac{3}{5}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

PLANING MACHINERY.

Planing, as applied to wood conversion, comprehends all the various operations of smoothing and giving accurate dimensions after the material has been cut out with saws. As a term, independent of its technical application, it should mean, to produce plane surfaces, which is indeed the main idea conveyed. It is, however, as said, applied to nearly all operations performed with rotary cutters. Planing machines in their importance as wood tools rank next to saws, and follow too as next in the regular order of wood conversion. They maintain relatively a much more important place in wood than in metal cutting. In metal work the ruling form, so to speak, is cylindrical; in wood it is a plane or a rectangle. Iron is almost homogeneous as to fibre; wood must be continually disposed and worked with reference to the fibre.

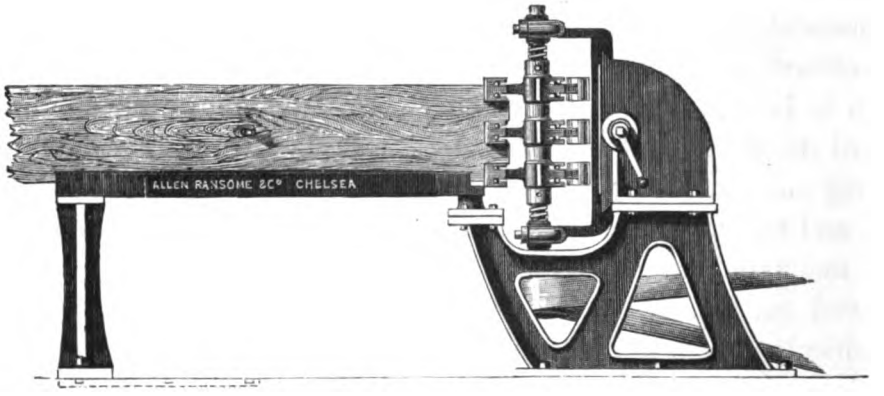
Planing machines, although in name and conversation are spoken of as a single class of machines, are nevertheless divided into three different classes, so different in the nature of their operation as to require some general term to distinguish them, and it will be the object here to apply such terms, with as much correctness as we can, and with a hope that in the future we can look to some classification of the machines, which the distinction in their several modes of operating certainly demands.

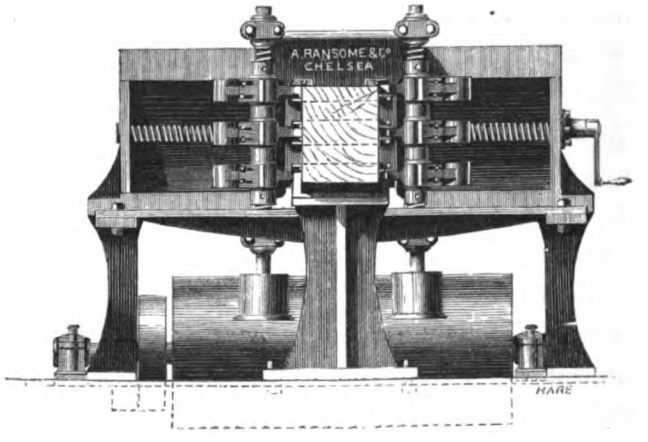
The first class will be termed the *carriage-planing machines*, in which the material is carried and guided on carriages, having its movement regulated and governed by extraneous guides, and independent of its own surfaces or shape; the guides becoming as it were an artificial surface upon which the material moves by the intervention of the platens or carriages.

The second class of machines will be termed *parallel-planing machines*, for producing parallel forms. This term has a peculiar application to the functions of such machines as have feeding rollers, and in which the material is fed over, and gauged from, a fixed bed

PLATE LXXXII.

(TRUE ELEVATIONS.)





TENONING MACHINE.

For Double or Triple Tenons on Heavy Timber. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

or gauging surface opposite the cutters. Parallel describes the nature of their work, and is at the same time a short and comprehensive term.

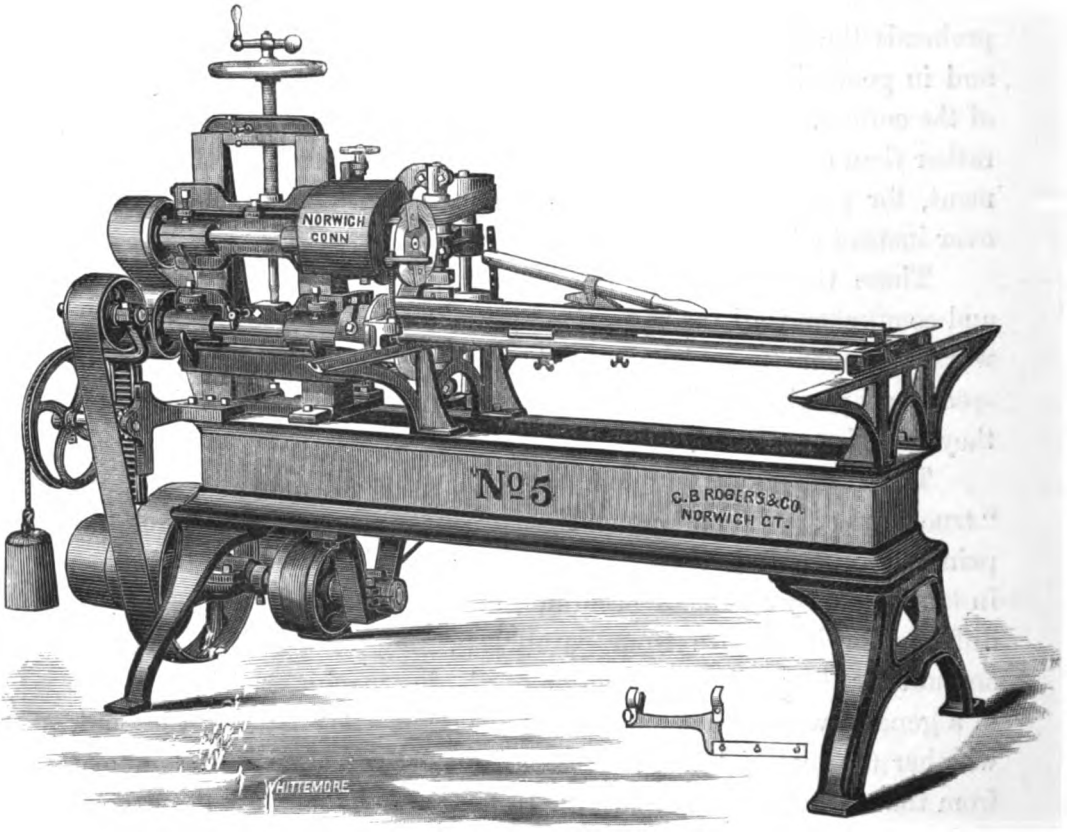
The third class of machines we will denominate *surface-planing machines*, such as have their action gauged from the surface of the material, cutting off from the surface a constant amount, without any reference to dimensions or to producing parallel lines. This comprehends the lower cylinder in such machines as plane both sides, and in general all machines wherein the stuff is passed over the top of the cutters. This feature is, however, one of usage in construction, rather than one growing necessarily out of the nature of the arrangement, for parallel planers have been made with the lumber to pass over instead of under the cutter cylinders.

These three constitute the different types of planing machines, and comprehend all the operations properly termed planing in woodwork. Under these, however, there are various modifications for special adaptation, which will now be noticed in the order in which they have been named.

The carriage-planing machine is the leading one, in fact the "true planer;" the one alone that produces planes, based upon the principle of guiding the cutters, or the material, which is the same, in true lines, by means of accurate guides. The operation is so very different in its nature from parallel planing that it is difficult to account for the popular conception of planing machines; which, stated in a general way, is that planers are about the same of whatever kind, whether the material or cutters are guided by a carriage or gauged from the surface of the material. In fact, so little has this thing been understood, that there are continual inquiries and suggestions about machines with roller feed for planing timber, and framing, that must be true and "out of wind." Carriage planers require a length equal to double the length of the material to be worked, that is, the track must be about twice the length of the platen or carriage, and consequently require a large amount of room; besides the feed movement is a reciprocating one, by which a large share of the time is lost in running back; their operation is necessarily much slower than that of

PLATE LXXXIII.

(PERSPECTIVE ELEVATION.)



TENONING MACHINE.

For Joiners' Work.—Arranged with scribing spindles.

C. B. ROGERS & Co., New York, U.S.A.

parallel machines, all of which creates a strong prejudice in favour of the latter; and it can be said, that in America at least the carriage-planing machine is used only when it is impossible to do the work on other machines.

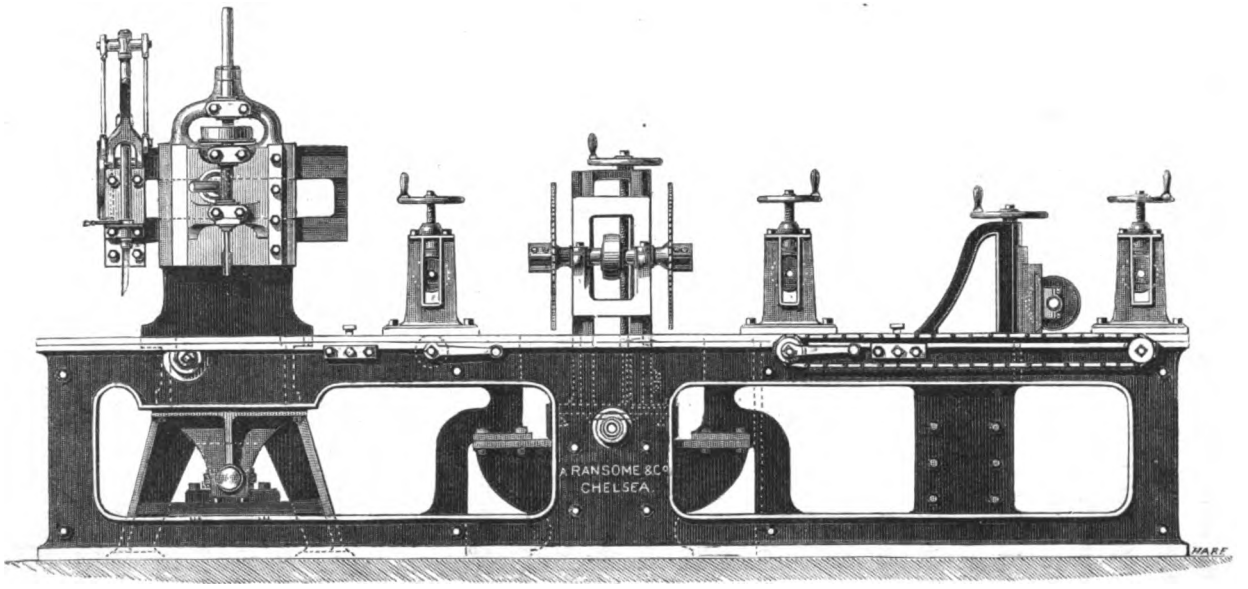
That the several objections noted are inherent in the machine, by no means follows. They are to be found in a large degree in the construction and arrangement of such machines; which has become by usage a kind of stereotype matter. During ten years past, the improvement of parallel planers has engaged nearly all the attention. It is evident that there can be no change in carriage planers that will dispense with the long framing, nor with the reciprocating feed; yet there is certainly much that can be done to secure a more rapid performance.

To realize how slow the work of a carriage planer, as now built, is, compared to a continuous or roller-feeding machine, we will assume that with traversing cutters, a carriage planer has a feed of 20 feet a minute, working one side at a time, and that at least two cuts are needed on each side of the piece to finish. In planing a square piece 20 feet long, there are at least eight motions of the carriage needed. Supposing that the time of running back to be enough, quicker than the feed, to compensate for setting, there would be required, at the least estimate, sixteen minutes to plane the piece. Now assuming that this work could be done on a parallel planer with a feed of 40 feet a minute, planing two sides, it takes but *one minute* of time to do the same amount of work, or, if the machine was arranged to plane all four sides at once, the time would represent at this rate of feed but one half of one minute, and bear a ratio of 1 to 32 to the performance of the carriage machine; here then is the secret of the prejudice in favour of parallel-planing machines. It is, however, folly to contrast them, for, as before assumed, it is in the nature of the operations impossible to apply them to the same purpose; and instead of fighting principles and laws that are incontrovertible, it is better to improve the carriage machines and attain a more rapid performance, without changing the nature of the operation.

Cutters that revolve in a plane parallel to the surface to be

PLATE LXXXIV.

(TRUE FRONT ELEVATION.)



MACHINE FOR PREPARING SOLE-PLATES OR RAILWAY CARRIAGE SILLS.

Arranged for Mortising, Boring, Gaining, Recessing, &c. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

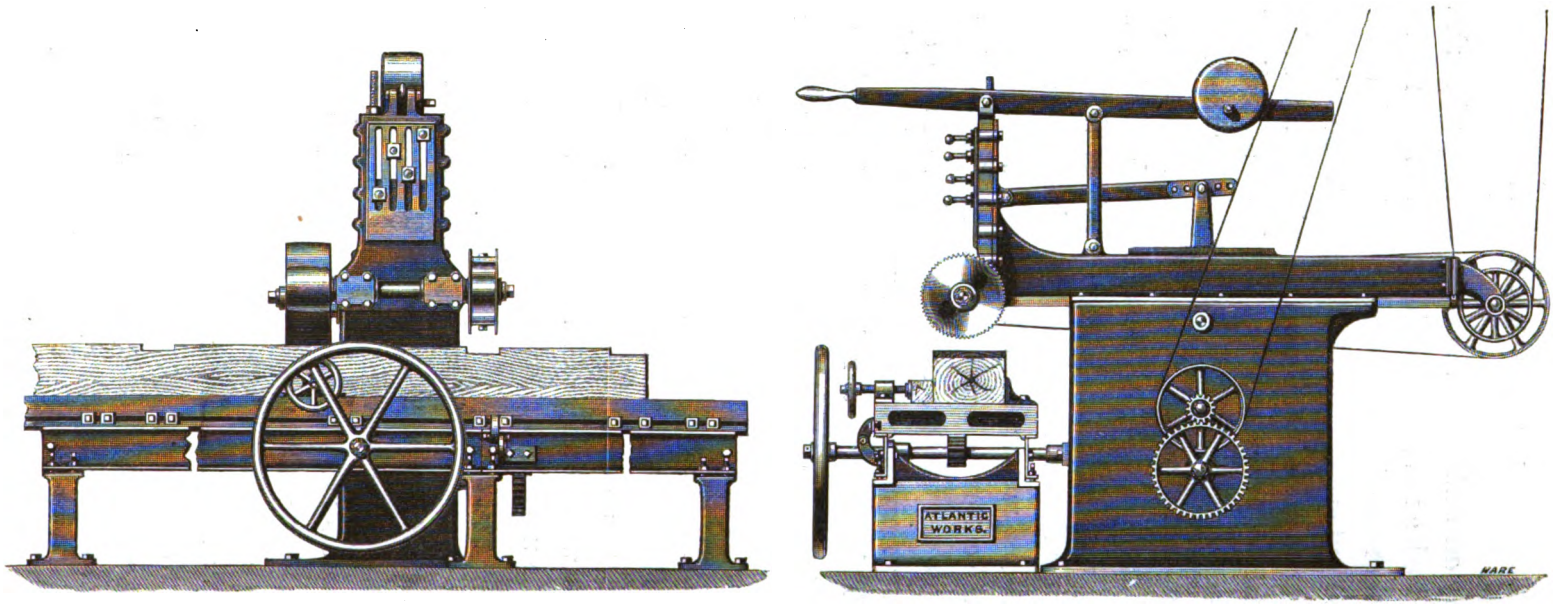
ALLEN RANSOME & Co., London, England.

planed *can only act with edges whose length is equal to the depth of the cut:* this is, indeed, a novel proposition, yet true. A traversing planer, with two cutters removing one-fourth inch in depth of wood, is using in the operation but *one-half inch* in length of edge, or one-fourth of an inch for each cutter; this is of course assuming that the edge is at right angles to the face of the wood, but to set in on an inclination does not alter the matter in principle. So far as severing the fibre, the length of effective edge is as stated. The bevel has reference to splitting of the wood, and not to the cross-severing of its fibres, which is the main part of the operation. To prove this is the necessity of continually changing the cutters in such machines, and also that they are continually dull, no matter how often changed.

To keep the cutters in a traversing cutter-head as sharp relatively as those of a cross-cylinder, they would have to be changed often enough to bring the same amount of "new edge" into operation in a given time. This, then, is a radical defect in carriage planes that have traversing cutters, and should restrict the use of this kind of cutter-head to a few special purposes to which it is peculiarly adapted. The amount of effective edge, without following out the nice distinctions laid down above, cannot as a rule be rated at more than one-half inch in length for each cutter, or one inch for a pair of cutters, or for one machine. For a cross-cylinder, or when the plane of rotation is at right angles with the face of the lumber, the amount of cutting edge that can be used is as the width of the lumber multiplied by the number of cutters; for instance, for a piece with a face 12 inches wide and with a cylinder carrying three cutters, the amount of effective edge is *thirty-six inches*, thirty-six times the amount we had in the other case: now assuming, as is generally the case, that by having these cutters 24 instead of 12 inches long, and that the lumber can be changed to different positions on the platen, so as to use different portions of the cutters at different times, we can further add to this estimate, and say that, at least, *one hundred and forty inches* of edge can be used. Now these propositions as to the application of cutters in the two cases are apparently absurd, but are verified by the experience of anyone who has practically operated the two kinds of

PLATE LXXXV.

(TRUE ELEVATIONS.)



RECIPROCATING CROSS-GAINING MACHINE.

For Cross-Grooving, Rebating, and Transverse Cutting generally. *Scale*—$\frac{1}{40}$th, $\frac{3}{10}$ths inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

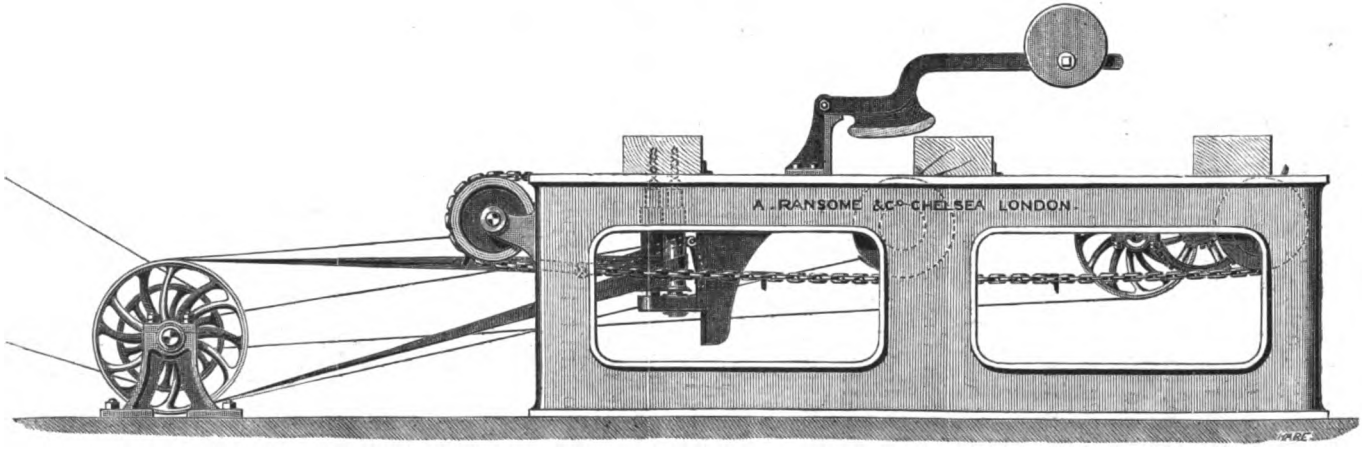
cutter-heads, and noticed their capacity. Here then is one improvement or change that can be made, by using the parallel cylinder instead of the traversing head. Three-fourths of the average work done on these machines can be done as well by one plane as the other, and in a large share of the work there is quite a gain by the parallel cutters, for the reason of the smoother surfaces left, which for ordinary painted work require no further preparation.

In the second place, we come to the planing of several sides of rectangular sections at the same time, as in parallel planers. In the comparison instituted, as to the relative speed of the work performed on the two machines, it will be remembered that the feed assumed in one case was twice that in the other. This was for two reasons, that have directly to do with the question of planing several sides of a piece at the same time, and are as follows: first, in the case of the carriage machine a mean was taken between the cutting capacity of the transverse and parallel cutters; secondly, the clamping and holding of the stuff to receive the action of the cutters. This last is the great reason of the superior cutting capacity of parallel-planing machines. The lumber is tightly clamped and held immediately at the cutters, and is capable of withstanding their heaviest possible action, in which case there is nothing left to limit the speed, except the bearings, or the injury of the cutters by heating on hard varieties of timber.

In the carriage planer it is impossible to use such effective clamping devices, which are, in the old patent of Samuel Bentham, quaintly described as "steadiment and presentment" of the wood; no better terms could be employed, for it is indeed a question of "steadiment and presentment," instead of the cutting agency that must control the speed of planing wood; a fact which presented itself to his mind seventy years ago, and has probably never since had a more thorough consideration. The operation of the carriage planer is predicated upon the timber being in a state of rest, not sprung from its natural position, so that when planed and released from its fastenings it will be perfectly true. To secure this result it is commonly fastened at its ends, or by side clamps, that are free to move transversely on the platen.

PLATE LXXXVI.

(TRUE SIDE ELEVATION.)



CROSS-GAINING MACHINE.

For Railway Sleepers.—Has continuous chain feed. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

The ends and one side of a piece are enough in any case for clamping and bearing purposes; which leave three sides of rectangular pieces that can be dressed at one operation on carriage planers. It might be urged that the disturbing action of the several cutters would force the timber out of line, but when we consider that the top or main cylinder would have the heaviest work, and that side cutters acting at right angles would not increase this trouble, there seems to be no practical difficulty; besides, strong bearing rolls can be used on the top of any timber stiff enough to require carriage planing, if proper attention is paid to packing it on the carriage, and in this way offer a very effective resistance to the pressure or jar from side cutters.

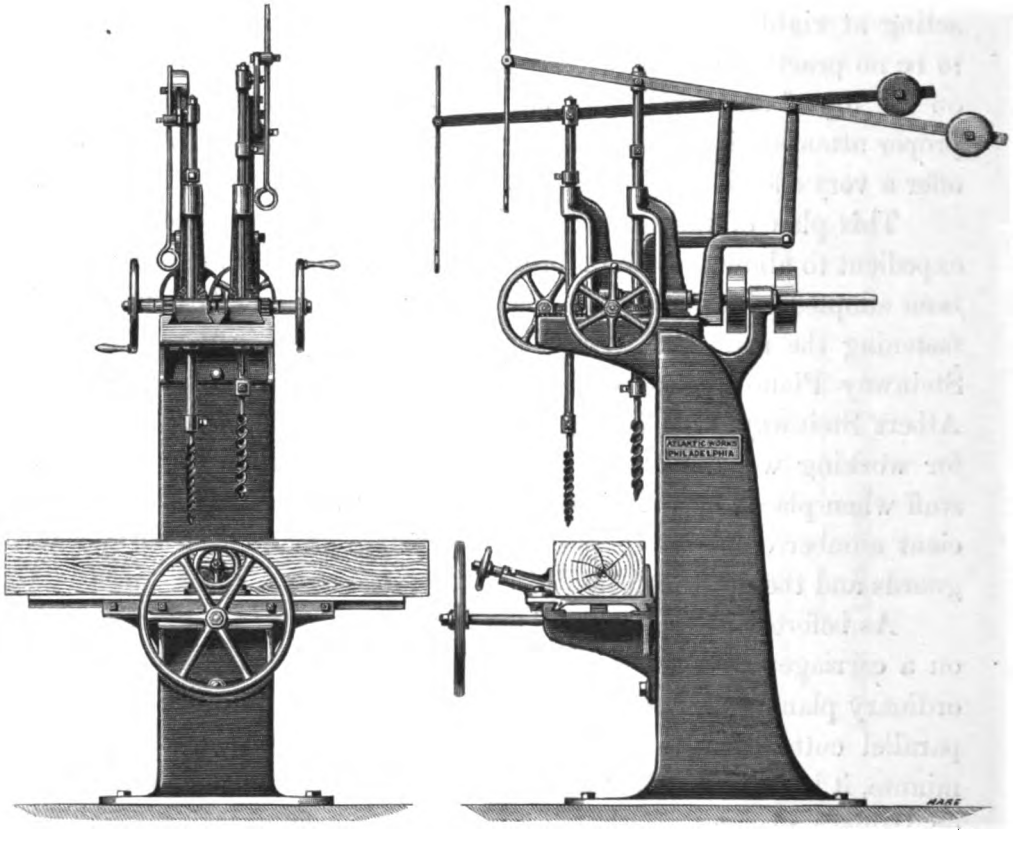
This plan of table packing for carriage planers is not only an expedient to allow the use of pressure rolls, but has in some instances been adopted with the "dead plate," as the only and best means of fastening the material. The plan has been adopted in the celebrated Steinway Piano Works, of New York, under the direction of Mr. Albert Steinway, who has given much of his attention to machines for working wood. No clamps or dogs of any kind are used, the stuff when placed on the platen is hurriedly "wedged up" at a sufficient number of points to prevent its springing, and is held by side guards and the dead plates only.

As before said, the ends and one side are enough to fasten material on a carriage; and are in fact all that can be used to advantage in ordinary planing. Assuming that a carriage machine is fitted with parallel cutters for three sides, and capable of feeding 30 feet a minute, it becomes a machine totally different from the old transverse or Daniel's planer. If the timber is afterwards passed through a parallel machine to dress the remaining sides, which is even preferable to finishing it on the carriage machine, the operation would certainly be fast enough and cheap enough to meet all demands in this direction.

The best plan would, however, be in most cases to work two *sides* at one operation, finishing at two; this would obviate the necessity of raising the timber above the face of the platen, as it could project over the side, and would besides leave the vertical face opposite the

PLATE LXXXVII.

(TRUE ELEVATIONS.)



COMPOUND BORING MACHINE.

Arranged with two spindles, having lateral and vertical adjustment; swivel table.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

cutter-head free for packing, to prevent it from springing. By the adjustment of the cutters two faces could at each operation be brought to a perfect right angle, finishing ordinarily at two motions of the carriage; and gaining three-fourths of the time needed for the same work on the traversing planer with one head. The triple-head carriage planer of Richards, London, and Kelley, shown in the plates, has just been arranged by the writer, with a view of demonstrating the correctness of the general propositions laid down, and to determine whether carriage planing cannot be done in a much less time, without increasing the cost of attendance. The details of carriage planers might be made the subject of a lengthy dissertation, but it is thought that the general remarks given are sufficient for the purposes of this treatise, which is intended, as stated in the preface, for the users as well as the makers of wood machines, and to whom the special details of construction would be devoid of interest.

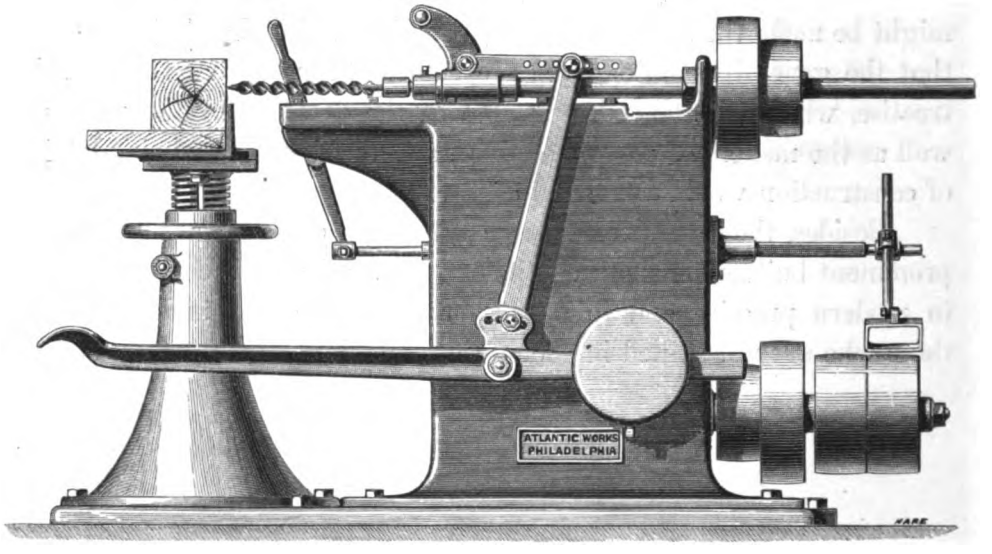
Besides, the several excellent engravings of carriage planers, by prominent builders on both continents, show all that is comprehended in modern practice, and in a manner that renders it understood by those who are not skilled in geometrical drawings.

PARALLEL-PLANING MACHINES.

This class of machines, which come next in order, we think it safe to assume are, as now made, among the most perfect in use for wood manufacture. Their extended use in America, and the enormous extent of the operations there, in what we will term "flexible" lumber, has given these machines the first rank in importance. As elsewhere stated the lumber of commerce in America is mainly one-inch boards, and so far has the ingenuity of carpenters carried the matter, that nearly every detail of a wooden house is made from one-inch lumber. The same is true of furniture manufacture, and even deep mouldings are now to some extent "built up" by matching

PLATE LXXXVIII.

(TRUE ELEVATION.)



HORIZONTAL BORING MACHINE.

To Bore at Angles.—Arranged with treadle or hand-feed.
Scale—$\frac{1}{16}$th, $\frac{3}{4}$ inch = 1 foot.

RICHARDS, LONDON, & KELLEY, Philadelphia, U.S.A.

from one-inch stuff, effecting not only a saving of material, but ensuring that the stuff is seasoned, which is, especially in walnut wood, a consideration of the first importance. Lumber one and one-fourth inch or less in thickness is so flexible as not to require carriage planing, or rather its rigidity is not sufficient to warrant it, and the more speedy process of parallel planing is the general one throughout North America.

The nature of the operation is that of passing the lumber between two fixed points, represented on one side by the pressure bars and cutters, and on the other by the bed, or abutment, reducing it to an exact parallel; the planed face being gauged from, and a reverse duplicate of, the other side. The elements of such a machine are essentially the cutting cylinder, front and rear pressure bars, expanding or adjustable feeding rolls, and a fixed bed or platen over which the lumber is passed. The origin of this machine, or rather of this class of machines, in the Woodworth patent, has been reverted to in the history at the beginning of the treatise. The lumber or board-planing machine is, however, to be considered only as the most important of numerous modifications, operating on the same general principle. The moulding machine for straight mouldings is of the same class. The chain-bed machine is also of the same type, although of very different construction.

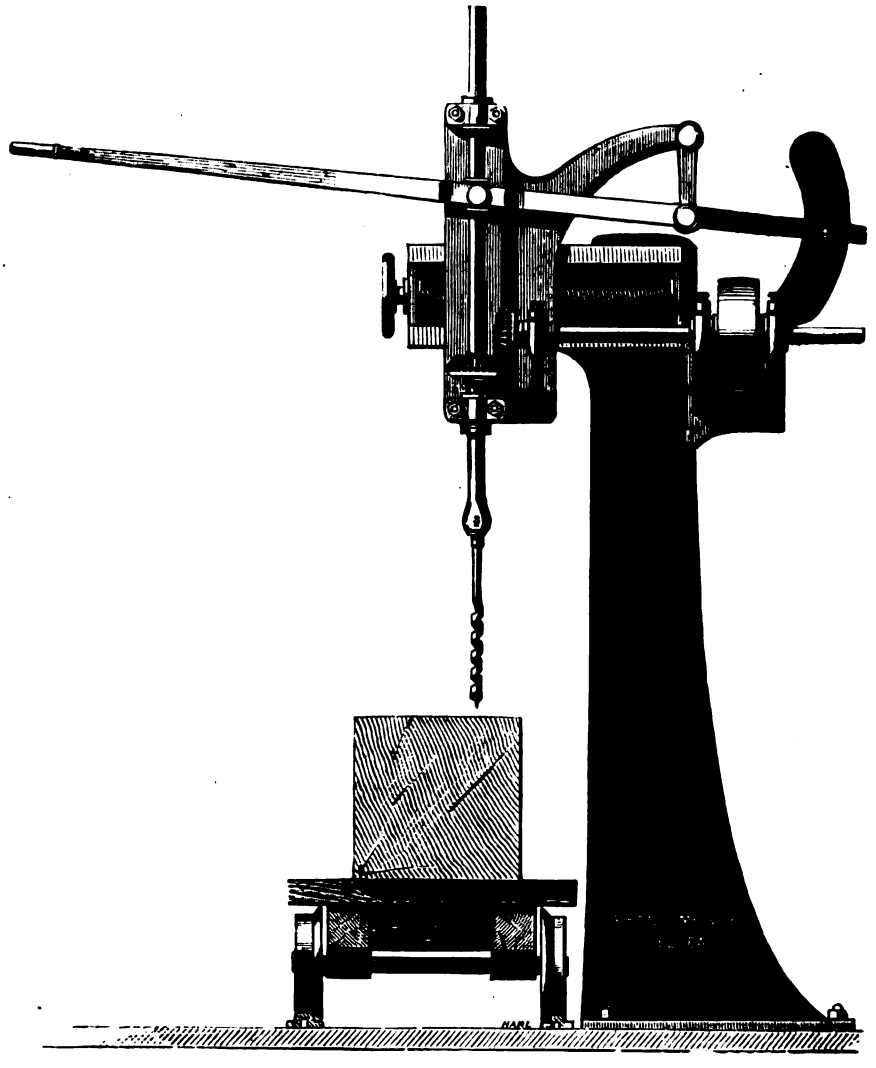
The parallel-planing machine we have intimated as having assumed in a degree a standard form of construction; it is possible to lay down some rules with regard to arrangement and details, which would be unsafe or useless in machines more likely to change.

The cylinders for carrying the cutters have been made in every conceivable manner, some with two, some with three, and often with four cutters; cast and wrought iron, steel and brass, have been used for material; the sections have been triangular, rectangular, and round. Cutters have been attached inside the cylinder to project through at the edge, fastened on the outside with screw bolts, and in some cases held by parallel dovetail keys.

The inference to be drawn from this varied construction of so simple a thing, is that either of the plans had something to recommend

PLATE LXXXIX.

(TRUE SIDE ELEVATION.)



VERTICAL BORING MACHINE.

With compound spindle movement. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

them, and that all were good; and further, that there is nothing in the operation of the cutters sufficiently apparent to indicate any specific plan of mounting them.

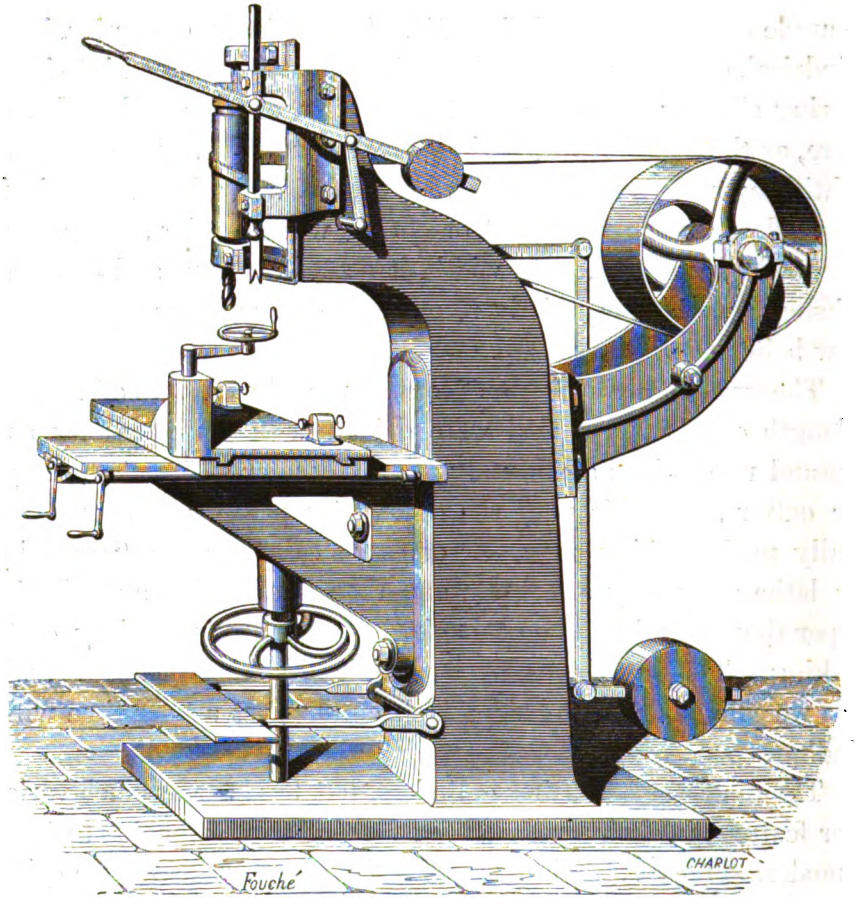
The plan of fastening last named by means of keys is no doubt a novel one to most builders of planers. It is especially applicable to the radial cutters described in a former article, and is the best when the angle of the cutters admits of it. The cylinder, or carrier, is made cylindrical, of wrought iron; dovetail grooves are planed into its face, tapering slightly from one end to the other, or from both ends to the centre, as the length of the cylinder may determine. The cutters are slightly tapered from the edge to the base, and when keyed in it is impossible for them to fly out or spring while cutting. For narrow cutters of 6 inches or less in width, it makes a secure and cheap plan of fastening, and is especially recommended for extreme speeds where screw bolts are at best unsafe.

The writer has in his practice constructed cylinders of 20 inches in length on this plan, that were driven with perfect safety at six thousand revolutions a minute, with a diameter of 5 inches, carrying four cutters. In this plan the cutters for planing flat surfaces are usually made solid from a bar of cast steel, the edges "turned off" in a lathe after they are fitted, and then hardened to a much higher temper than would be practicable if there was any possibility of their breaking. They can be removed with facility when necessary, which is, as we can add, very seldom; such cutters last a long time without grinding.

The diameter of cutting cylinders, too, has been as much varied as other features in their construction, varying from 10 inches to 4 inches in modern practice. The idea of a flat curve with a large cylinder seems to have but little to do with the result, and although a statement that will seem irregular, the smoothest planing is now done on machines with cylinders of small diameter; a result, however, which must be attributed to other reasons than the sweep of the cutters, and is no doubt to be found in the angle of the cutters, which is usually more acute with the large cylinders. Taking the experience of the last ten years among the various builders, with such data as

PLATE XC.

(PERSPECTIVE ELEVATION.)



ROUTING MACHINE.

For Mortising, Boring, and Recessing.

F. ARBEY, Paris, France.

there is from which to assume a standard for planing cylinders, we feel warranted in presenting the following dimensions and rules for ordinary planing, applicable to machines of any kind.

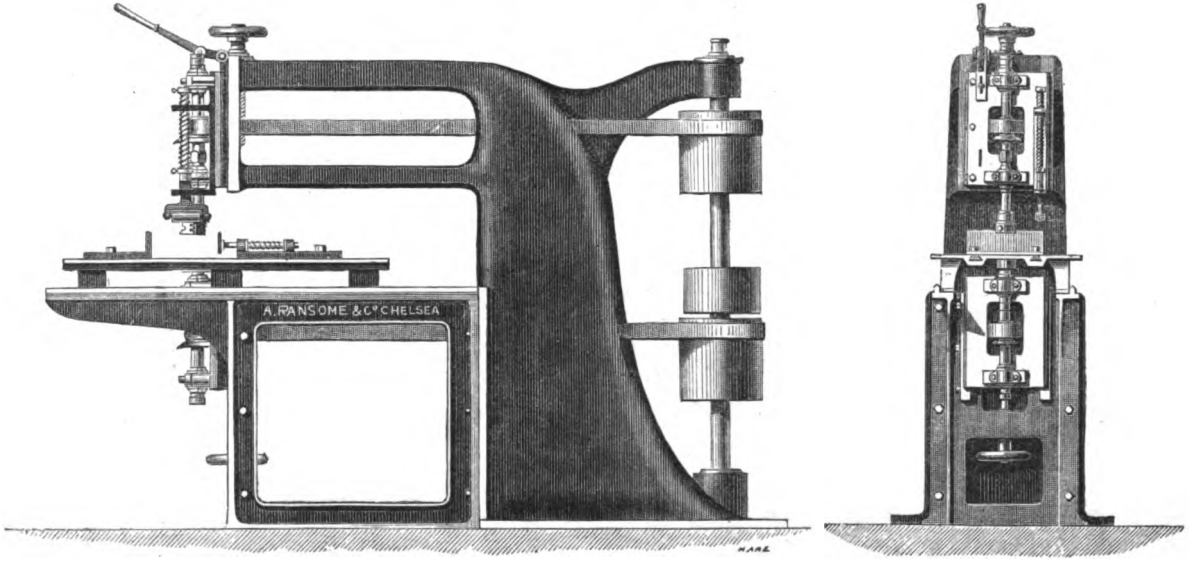
They should be made of forged iron of the best quality, or of steel, which is preferable, and in all cases solid with their spindles, or bearings. The diameter not more than 8 nor less than 6 inches. Three cutters are better than two, or four, as this arrangement leaves about the proper amount of "throat room" between the heel edges for shavings. The angle of the cutters should be such as to allow clearance on their back for a steel washer one-eighth inch thick, and the head of a standard bolt. The width of the cutters should, as a rule, be at least one-half the diameter of the extreme sweep of the cylinder; their thickness never less than three-eighths of an inch, clamping bolts should be carefully fitted, and made of the finest iron of a soft quality (Swede or Norway brands are good), their diameter not less than three-fourths of an inch. Unless spaced nearer together than 4 inches they should be larger.

These proportions, for each of which there could be good reasons given, may seem empirical in the manner presented. They are, however, based upon deductions from actual practice, and will be found, so far as they are explicit enough for use, to be reliable. Safety is one of the first points to be regarded in arranging planing cylinders, especially in the matter of cutter screws, which are subjected to a great centrifugal strain as well as the strain of the work, which with straight knives consists in a succession of blows. Besides, the operator, with a feeling of guarding against danger, generally strains them down with all his might, augmenting the very danger he is trying to guard against; hence the rule as to soft iron, which is less subject to what is known as "cold short" fracture.

The lips or projection of the cylinder beneath the edge should not be carried out to interfere with the shavings, and be so shaped as to effectually guard against the shavings driving under the knife. The theory of a cap, or "ship breaks," as it is sometimes called, can be safely disregarded, as both wrong in theory and inoperative in practice, on the ordinary planing machine. This statement is made, as we are

PLATE XCI.

(TRUE ELEVATIONS.)



ROUTING MACHINE.

For Moulding, Recessing, Rebating, Shaping, &c.—Arranged with top and bottom spindles.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

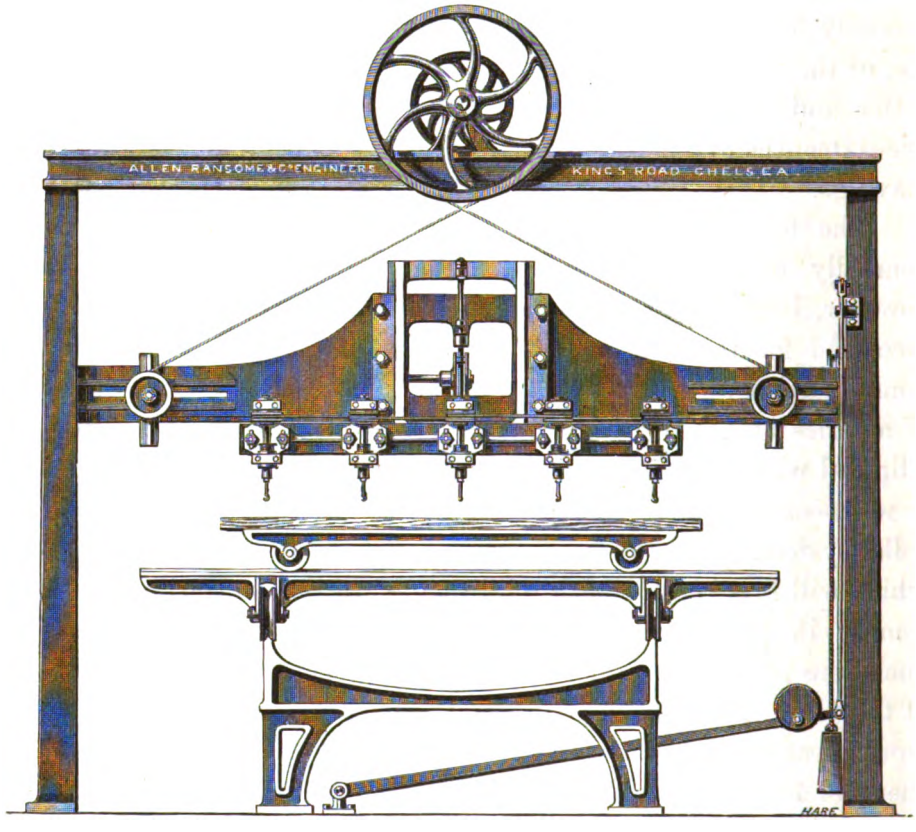
ALLEN RANSOME & Co., London, England.

fully aware, in opposition to a very prevalent opinion on the subject of lips, to prevent the tearing of the wood, but certainly a mistaken one in practice; not but that such guard lips could be, and are in a few instances, made to operate with the proper effect, but such cases are so rare, and their obstruction to the action of the cutters so serious, that the best rule is without doubt to keep them out of the way, and if a necessity for them exists, change the angle of the cutters, if for constant use, or the angle of the edge for special cases, which will be found the better and more effective plan. The edges should be bared from five-sixteenths to one-half inch, to allow free cutting and clearance for shavings.

The feeding mechanism of parallel-planing machines consists generally of adjustable or expanding rollers. Other plans have, however, been adopted, one of which—the chain bed—has been quite successful for the rougher class of planing. Messrs. McDowell and Sons, of Glasgow, some years since adopted a feed motion consisting of a series of griping cams operated by crank motion, driven with elliptical wheels to obtain uniform movement. It seems, however, that it was soon abandoned, either from want of any advantage over the roller system, or its greater cost and complication. The feeding rolls which will first be noticed, are all that is wanted for feeding ordinary lumber in planing machines, and their almost universal use for analogous purposes in other machines is an evidence of the correctness of the plan. No objection exists to the rolls themselves, and whatever trouble has arisen in their use has been due to the gearing for driving them, or to some very faulty arrangement. The points about which there exists the greatest difference of opinion, and in which construction varies most, is in their diameter and the means of gearing and driving them. They are made from 3 inches to 24 inches in diameter, as extremes, and as we find in some cases the large rolls fluted and the smaller rolls smooth, it is safe to infer that the conditions in the two cases are not very well understood among the builders, and also that, as in the case of the cylinders, it is not a matter of any great importance; yet there are in this, as in all other matters relating to machine construction, certain premises or conditions, which if under-

PLATE XCII.

(TRUE FRONT ELEVATION.)



DUPLICATING AND CARVING MACHINE.

Has compound carriage movement, tracer guide, and four spindles.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

stood and considered must lead to at least an approximate standard for dimensions. To govern the proportions of feeding rolls we have the following propositions:

First.—For smooth rolls, their tractile force is increased with the amount of contact between the roll and the lumber, and the *larger* the diameter the greater their feeding power.

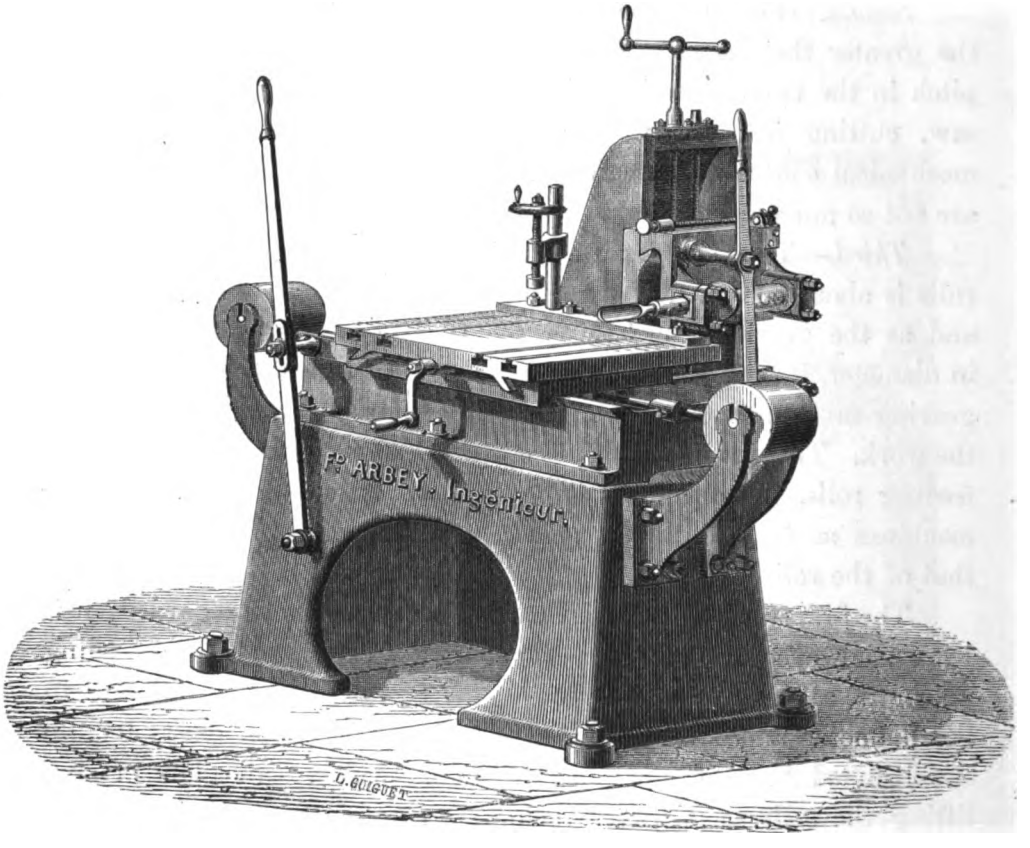
Second.—For fluted or corrugated rolls, the *smaller* their diameter the greater their tractile force; supposing the flutes to be of uniform pitch in the two cases, they become in a small roll like the teeth of a saw, cutting into the wood and dragging it forward by positive mechanical contact, whereas, in the large roll, the edges of the flutes are not so much exposed.

Third.—The amount of driving force needed to propel the rolls is about constant, if we consider it applied at their periphery; and as the gearing for driving the rolls is in most cases no larger in diameter, it naturally follows that the diameter of the rolls and the gearing must be increased until the wheels are strong enough to do the work. This last is the prime condition to regulate the diameter of feeding rolls, the one indeed to which experience has led, in such machines as have expansion gearing whose diameter corresponds to that of the rolls.

The first two conditions are not, of course, to be disregarded; it is better, however, and cheaper in most cases, to increase the feeding power of a machine by increasing the number of rolls, rather than the diameter and force of a single pair. Objections exist, too, to small fluted rolls, on account of their marking the lumber and lifting the ends as it leaves them. Rolls from 6 to 10 inches diameter are the best; spur-wheels to match rolls of this size of coarse pitch, and applied at both ends will do their work without breaking, and two pairs of such rolls, if properly arranged, will feed any kind of stuff in a machine that has only rotary cutters. The elastic compression of the top rolls should be in all cases by means of weights, especially in America, where the irregularity of thickness of the lumber calls for a very free yielding of the rolls. For clearing rolls behind the cutter, springs do very well. For wide machines, intended

PLATE XCIII.

(PERSPECTIVE ELEVATION.)



MORTISING, ROUTING, AND RECESSING MACHINE.

With compound table movement, and also spindle movement.

F. ARBEY, Paris, France.

for plane surfacing, the top rolls should have an oscillating adjustment, to adapt them to varying thicknesses of the two edges of the lumber. For all machines, however, working 14 inches or less in width, a true parallel adjustment is all that is required, supposing of course the pressure bars, or rolls, to have independent adjustment at each end, so as to fit down upon the stuff.

The gearing for driving expanding feed-rolls of planing machines has also undergone a great variety of modifications since the Woodworth patent, especially in America, where these machines are so largely used and made. The most common plan for the extension gearing, that drives the top or yielding rolls, is that of four spur-pinions, two of which are keyed to the roll shaft, the other two forming intermediates, with their axes connected by links with bearings of the top and bottom rollers. The expansive gearing seen on the machines of S. A. Woods among the engravings is that known as the Whitney patent, and is one of the best in use; the intermediates being held by a single link, and having long and sufficient bearings to withstand the wear, which is quite rapid. The most popular plan with English builders is to mount the top rolls in radial swing frames, pivoted on the axis of a central driving shaft, the roller raising and lowering in the axis of a circle of which the swing frame is a radius. This plan is one that admits of the use of strong gearing, and for moderate expansion has many mechanical advantages to recommend it. The planing and moulding machine by M. Arbey seen in the engravings is a good example of a single pair of rolls geared in this manner.

Some builders, both in England and America, use bevel wheels to drive the yielding rolls, an arrangement that must certainly be predicated upon coincident movement at each end of the roll, as the bearings and wheels would be soon destroyed if the rolls were permitted to oscillate with the variations of ordinary rough lumber.

PLANING AND MATCHING MACHINES.

Parallel-planing machines, with vertical spindles for tongueing and grooving flooring boards, ceiling, &c., are generally termed planing and matching machines, or flooring machines. When fitted with top and bottom cylinders and matching spindles, they become quite complicated in their construction. The combined planing and moulding machine by Messrs. A. Ransome and Co. shown in the engravings has six independent cutter spindles, the largest number that has, within the knowledge of the writer, been applied to one machine to operate on one piece. In this case there are two preparatory cylinders, one on the top and the other on the bottom, that reduce the lumber to a true parallel before it is acted upon by the finishing or moulding cutters. Matching machines are in America usually built of sufficient width to do surfacing on wide boards, as well as matching, the vertical spindles being in that case either removed to one side, or dropped down in sliding frames; in some instances the heads are so attached, that when removed, the board in surfacing passes over the top of the spindles without changing their position. This double arrangement, however, conflicts with the opinion expressed in another place in reference to such combinations, and the demand for machines so built must be attributed, either to a mistaken economy in first cost, or a want of sufficient business to keep the machine constantly employed in either capacity.

It is common to fit them with a bottom cylinder, which is often necessary in working ceiling or flooring; this adds but little to the first cost, and nothing of importance to the complication.

The machines of S. A. Woods seen in the engravings are of the largest class made, and represent in their general arrangement a plan of construction that is based upon long experience in the most critical market for such machines that there is in any part of the world; they are of course intended for large planing mills, a business that is not as a rule connected with building, further than the preparation of material for the general market.

s, &c., &c.

CHAIN-BED PARALLEL PLANERS.

This somewhat anomalous kind of wood-planing machine was invented some eighteen years since, with the object of evading the notorious Woodworth monopoly, by James Farrar, U.S., an object which it certainly attained, so far as surfacing boards on one side. Although mechanically one of those things that presents an aspect of impracticability, its success is sufficiently attested by the fact that not less than two thousand such machines have gone into use in America, and are at the present time more largely made than at any previous period.

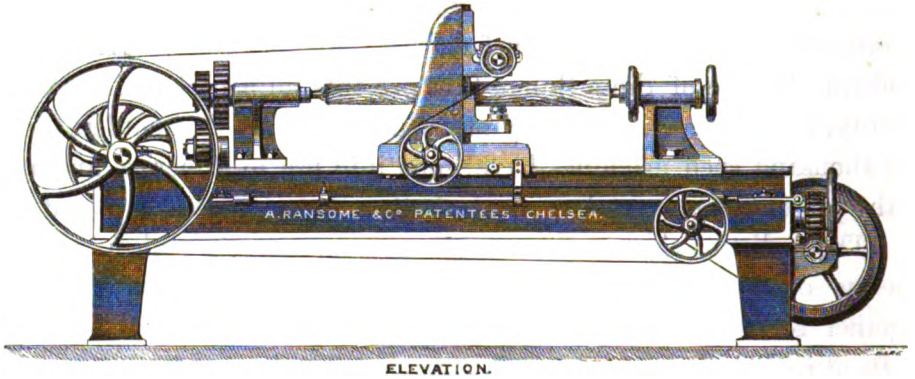
Their distinguishing feature is the feeding mechanism, which consists of a continuous or endless chain of narrow bars, linked together so as to be flexible. This chain is carried on wheels and shafts at each end of the machine, passing under the cutting cylinder, at which part it is supported on bearing bars set parallel to its motion. In front and behind the cutting cylinder there are the usual pressure rolls, that keep the lumber down upon the chain, creating the friction or traction that carries it through the machine. This device of a chain platen or bed is quite an old one for other uses, but it would hardly be supposed that its bearing surfaces under screw pressure would, without lubrication and covered with dust, last and give good results as to durability.

We regret that the delay in engraving will prevent the introduction of an illustration of a heavy machine of this class which was at first intended. It is, however, a machine which has nothing to recommend it for an European market, and is too well known in America to need even the brief description given.

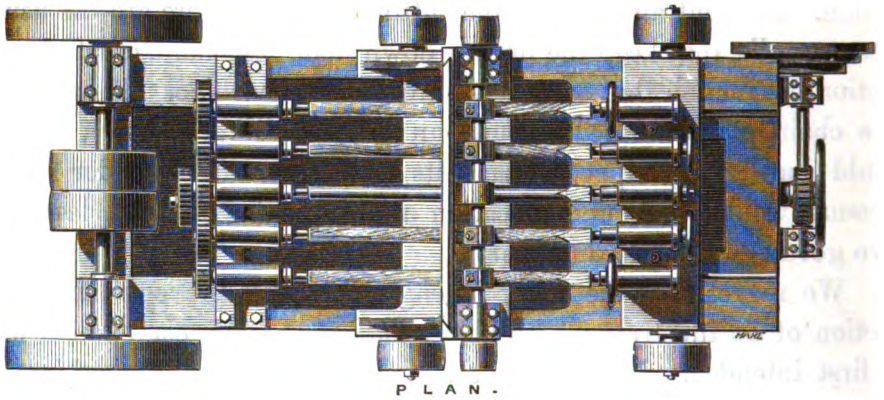
In the arrangement of these machines as now built, there is one feature that challenges criticism, and seems at great variance with what would seem to be suggested by the nature of the operation; we allude to the plan of adjusting the bed to and from the cylinder. One of the incontrovertible laws, not to say axioms, of mechanics, is that when two parts are to be moved relatively, move that one which

PLATE XCV.

(TRUE ELEVATION AND PLAN.)



ELEVATION.



PLAN.

DUPLICATING MACHINE.

For Shaping Spokes, Gun Stocks, Lasts, Handles for Tools, &c., &c.—Is multi-spindled, and receives four blanks. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

is easiest to move, a rule which is certainly violated in the ordinary construction of the chain-bed planing machine, for it is hardly a debatable question as to the cost and convenience of adjusting the cylinder and pressure rolls, or the bed and driving gear, in fact all the machine except the frame.

The fixed cylinder was no doubt at first used to secure convenience in belting, but to contrast this with the inconvenience of having the bed continually varying its position, as the thickness of the lumber may require, would be to choose the greater of two evils.

The durability of such machines is dependent almost entirely upon the construction of the chain, which should be of hard, close, cast iron for the travelling bars; the stationary bars should be faced with *tempered* steel, not soft steel, which is even worse than soft iron. The connecting links should be of the best iron, riveted with steel.

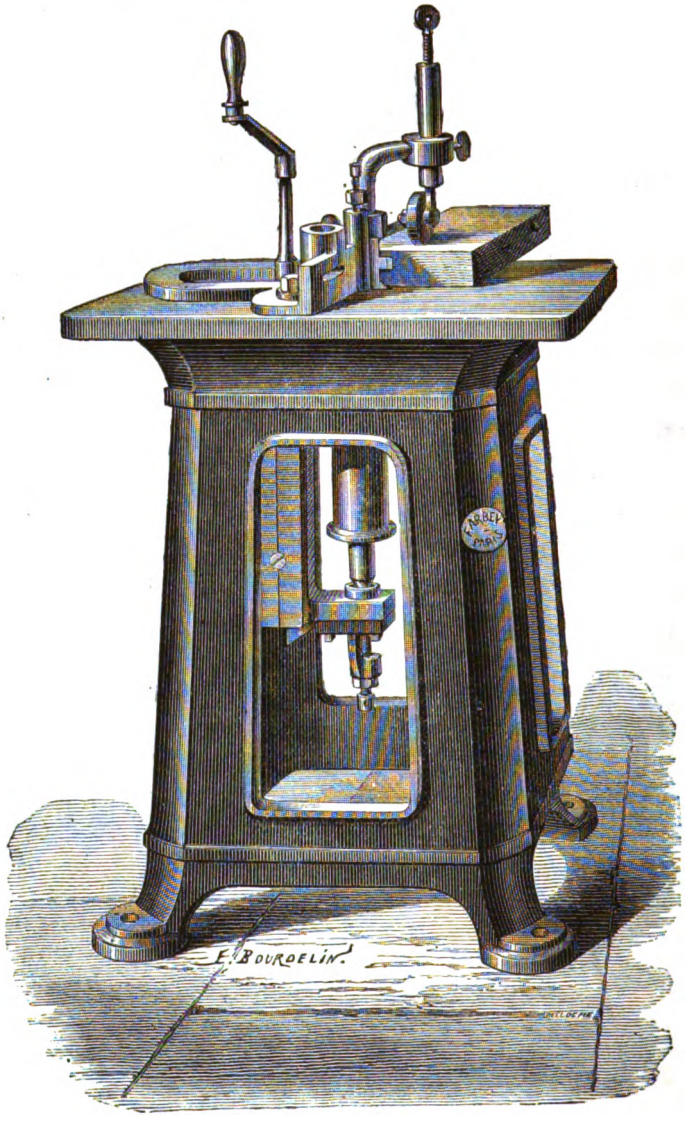
The danger of abrasion occurs in starting a new machine, and when once begun can never be safely guarded against in future. These machines are built as a rule 24 inches or more in width, and are used for surfacing pine boards in the lake districts of the United States, where the cost of planing is almost compensated in the reduced weight of the lumber for shipment. The enormous amount of forty thousand feet, and even fifty thousand feet, has been passed through one of these machines in ten hours. To do this, two boards at once, unless very wide, are fed through. So far has this system of lumber-planing been carried, especially in Chicago, that in the transition of lumber from one railway train to another, the planing is no more, nor even so much, considered as the handling.

SURFACE-PLANING MACHINES.

Machines that gauge from the surface of the lumber, cutting away a constant amount, are of very limited application in wood working, and can at best have only the smoothing of the surface

PLATE XCVI.

(PERSPECTIVE ELEVATION.)



MOULDING, SHAPING, AND GROOVING MACHINE.
With single spindle.

F. ARBEY, Paris, France.

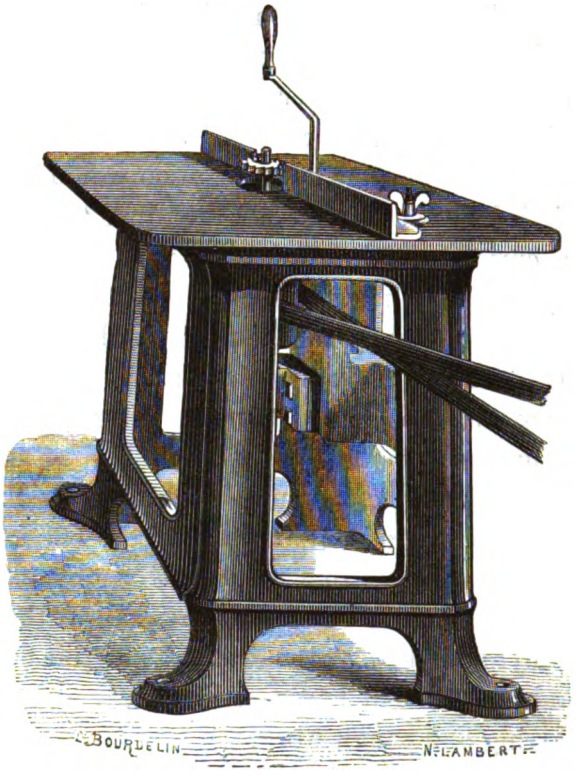
for an object. The bottom cutters of an ordinary planing machine, that planes both sides, operate upon this principle, and require to be arranged accordingly, with adjustment of the rear bed, and either of the cylinder or front bed, in order to regulate the depth of the cut. Planing machines of this arrangement, with a bottom or overcutting cylinder, are so little used that no mention would have been made of them here if it had not been to call attention to a fact that is often regarded as a curious one in connection with their operation,—that of their always planing more smooth than those working on the top of the lumber; a thing that has no doubt been noticed by every experienced operator of planing machines. The cause is to be attributed in part to the fact of the cut being continually equal at all points, and just heavy enough to get the best result as to smoothness; but more especially to the more important one that the gravity of the cylinder is acting *with* the strain of the cut and against the fixed part of the bearings. In a top cylinder, any play or looseness in the bearings is communicated to the face of the work by the gravity of the cylinder being insufficient to keep it down, or by first the gravity and then the cut having the mastery at intervals, tending to continual jarring and rough work.

The most important modification of the wood-planing machine that can be included in this class is that of B. D. Whitney, engineer, of Winchendon, U.S., illustrated by the engravings. It is one of those bold and original inventions, which upon theoretical deductions would scarcely have been made.

It is rather to be termed a scraping machine, or a scraping planing machine, as the cutting action is by means of fixed steel scrapers, whose flat face is at right angles with the face of the board. An edge is turned with a "steel" in the ordinary manner on a cutter or scraper, whose length is equal to the width of the machine, sometimes 24 inches. This scraper is fixed in drawers working in seats planed across the machine, so as to facilitate their removal for sharpening. This, with an elastic platen opposite the cutters or scrapers and powerful feeding rolls, constitute the main elements of the machine. Its purpose is to smooth parts of furniture, chairs,

PLATE XCVII.

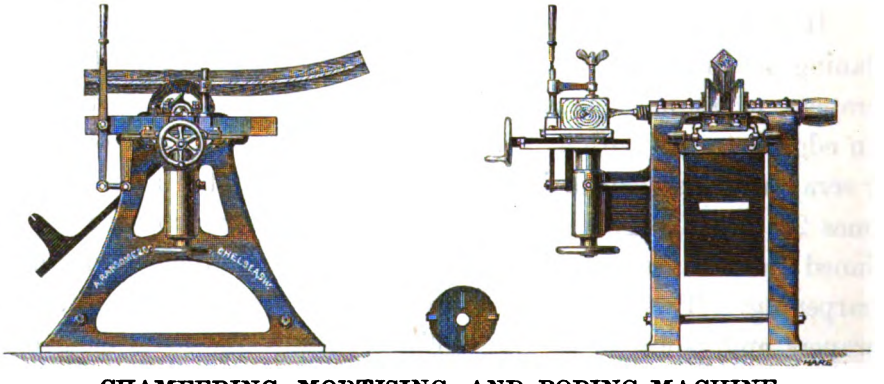
(PERSPECTIVE ELEVATION.)



WOOD MILLING AND SHAPING MACHINE. ***For Straight or Curved Lines.***

F. ARBEY, Paris, France.

(TRUE ELEVATION.)



CHAMFERING, MORTISING, AND BORING MACHINE.

Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

piano work, &c., after it has been planed in the ordinary manner, and reduced to a parallel thickness. Its action, especially in the harder varieties of wood, is very perfect, and being directed to a purpose which had previously been one exclusively of hand labour, the saving effected is very considerable.

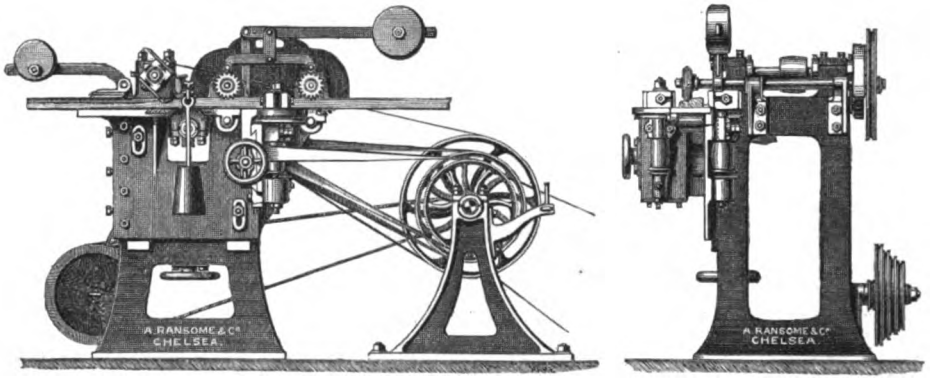
MORTISING MACHINERY.

Mortises and tenons represent in wood work what bolts and rivets do in metal work,—the mechanical means of connecting the different parts of frames and structures: the analogy, is, however, far from complete. Metals are joined by fusion or welding; they are also connected without special reference to fibre, while in wood work all connections or joints must be mechanical, and every piece arranged with strict reference to its fibre. Transversely, it has no capacity for withstanding tensile strain, at least none that need to be practically considered, while parallel with the fibre its coefficient compares with many metals. Its employment, however, to resist tensile strain is rendered impracticable, or nearly so, from the want of some means of connecting its ends, so as to represent a continued strength throughout such joints. As remarked, mortises and tenons are the ordinary plans for joints, and are at best but a poor expedient compared with riveted or bolted ones in metal work. In civil engineering structures wood is largely used for withstanding compressive and transverse strain; the whole being clamped and held by iron bolts that receive the tensile strain, a combination that bids fair to last yet for a long time, especially in countries where the relative cost of wood and iron invites it.

After wood has been sawed and planed to true dimensions, the next process is to join it together, which brings us to machines directed to this purpose, and as mortising naturally precedes tenoning, mortising machines will be first noticed. They are divided

PLATE XCVIII.

(TRUE ELEVATIONS.)

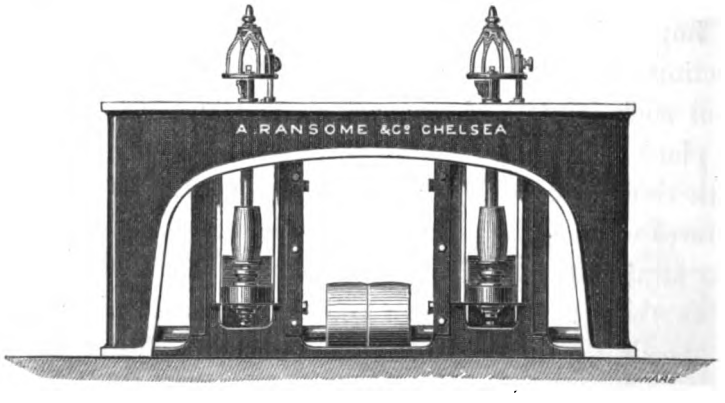


MACHINE FOR STRAIGHT MOULDINGS.

To 3 inches wide. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

(TRUE ELEVATION.)



MACHINE FOR MOULDING AND SHAPING.

With vertical spindles and safety shields. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

into two classes,—reciprocating and rotary machines. The first class of machines as now constructed can be again divided into four modifications, as follows: first, the "graduated stroke" machine, in which the chisel-bar has a graduated reciprocating motion, commencing from a still point, and progressing downward into the timber, returning to the starting point at each return stroke—differing from a variable eccentric in the matter of requiring a stroke but little longer than the depth of the mortise. Variable cranks or eccentrics that operate the chisel-bar by an increased throw, in both directions, above and below the *centres*, have been applied in all conceivable forms to mortising machines without any satisfactory result.

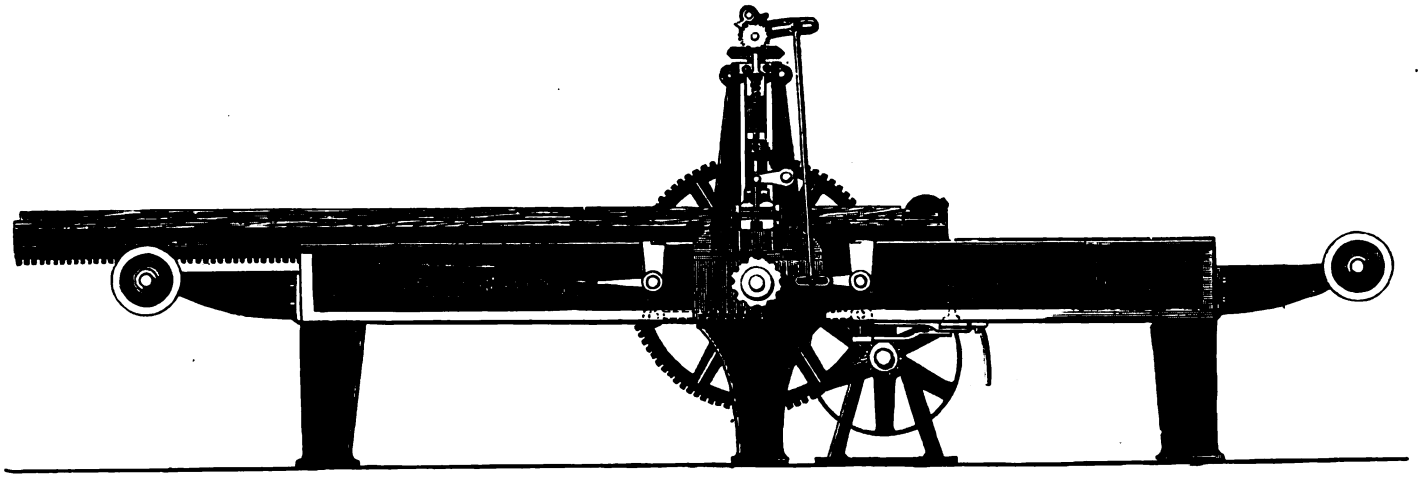
2nd. Another class of machines is that wherein the reciprocating parts, including the crank-wheel, chisel-bar and connections, are all brought down towards the timber, the chisel having a continuous motion, with a uniform range and a positive eccentric.

3rd. We have the machines with the chisel-bar or its connections elongated to give the stroke, the bar and chisel having a continuous reciprocating motion, but capable of being extended to the depth of the mortise, and yet resist in its joints the force of the blow. The writer designed and patented, in 1866, a novel modification of this machine, wherein the operator was relieved from any jar or labour in operating the chisel-bar, but at an expense of much complicated mechanism that was inconsistent with the conditions required in a mortising machine.

4th. Another modification is that of machines arranged to move or feed the wood to the chisel, which has a continuous reciprocating motion, the operating parts being only a crank-shaft, a plain chisel-bar, and connection. These machines are the most simple that can be constructed, and have every needed function for all kinds of work when the material is not too heavy to be raised to receive the action of the chisel. They can be operated at a speed that would soon destroy machines with more detail; and have superior claims, on account of their simplicity, for general uses. They can be operated at 600 blows a minute for joiners' work, and when the bed or table is properly arranged, no inconvenience from jar is felt by the operator in

PLATE XCIX.

(TRUE ELEVATION.)



MACHINE FOR MAKING WAVE MOULDINGS.

Has carriage feed and reciprocating scraping cutters. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

raising the table. At a rapid motion the jar is absorbed by the inertia of the table (which is generally made heavy), and is hardly communicated to the treadle.

The high speed of wood-cutting machinery that has so often been alluded to, is a condition which is peculiarly antagonistic to reciprocating motion, and when the two things meet in a machine, the result is easy to predicate: jar, vibration, destruction, wear, and breaking of the parts is the result. Steam hammers among engineering tools, and mortising machines among wood tools, represent this abnormal combination. In steam hammers the elasticity of the propelling force, however, protects the reciprocating parts, and prevents, in a measure, vibration of the framing and the shock arising from the impact of the blow; but in the reciprocating mortising machine, all is wrong, no saving condition exists; even that of slow speed is impracticable.

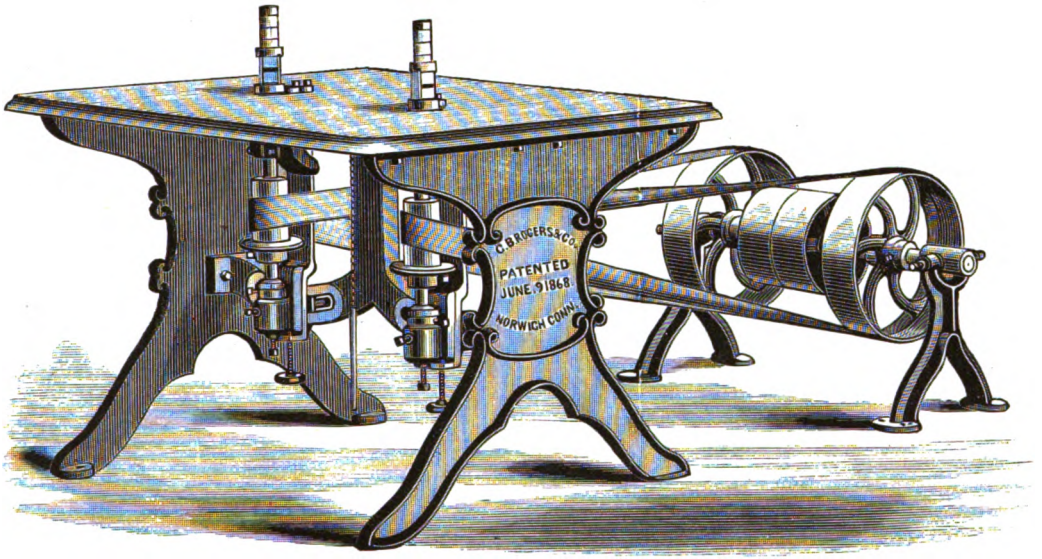
So many and so formidable have been the difficulties to encounter in machines of this kind, that European builders have avoided them; and a large share of the mortising in England, and nearly all upon the Continent, is either done by hand or with rotary machines. In America, either through an ignorance of the difficulties to be encountered, a greater boldness in such things, or the high price of labour, mortising machines of the various types noticed are extensively made and generally used. Two firms of the writer's acquaintance have built and sold upwards of *two thousand* reciprocating mortising machines during fifteen years past; another firm, certainly five hundred in the same time.

To develop the reciprocating mortising machine, as it has been done in America, requires three things: highly-skilled labour, a long experience, and very limited amount of engineering knowledge with the builders of the machines. The last condition is rather a curious one, but a skilled engineer, conversant with all the principles of the operation and difficulties to be encountered in making and using such machines, could not conscientiously recommend them, except for the lighter class of work, and would enter upon their manufacture only to meet a positive demand.

The second and fourth modification of reciprocating mortising

PLATE C.

(PERSPECTIVE ELEVATION.)



MOULDING AND SHAPING MACHINE.

Intended for Irregular Forms.—With vertical spindles; spindles revolve in opposite directions.

C. B. ROGERS & Co., New York, U.S.A.

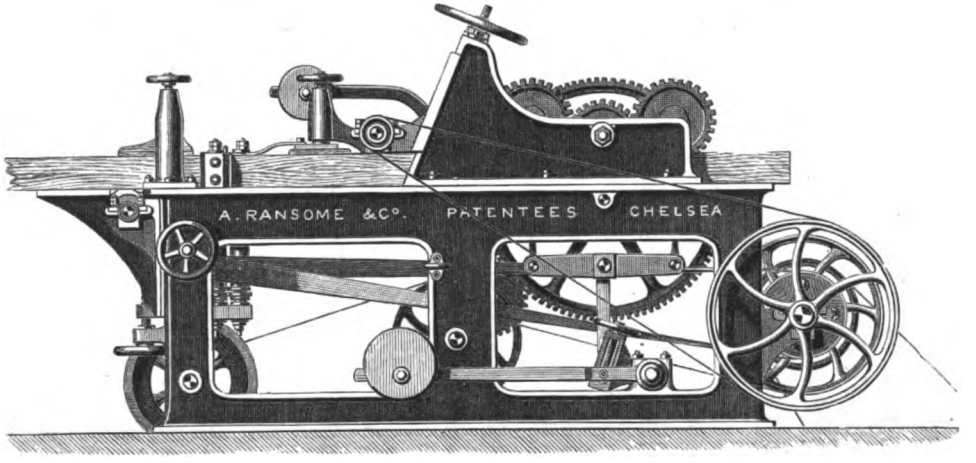
machines is represented in the machines of Richards, London, and Kelley, among the engravings. The graduated stroke machine, of which two examples are given, Plates LXXV., LXXVI., has been built under a great variety of designs, involving ingenious mechanical appliances which could not be intelligently explained except by means of detailed geometrical drawings. The very meaning of the term in its technical sense, as applied to the machines, is not easy to explain. It relates, as before stated, to a reciprocating movement of the chisel-bar, the range in one direction being to a fixed point; in other words, when the bar is set in motion, as it is at each mortise, it does not, as in a crank motion, vary above and below its position when still; but is projected downward only, returning to the same point continually on its "up stroke," so that its effective range for cutting *equals the whole stroke*, or nearly so. The machines of the second class, with a movable eccentric shaft and reciprocating parts, are the most simple in their construction and less liable to derangement than any that have what we will term "chisel-bar feed;" and when the movable parts are heavy enough to absorb the effects of the reciprocating movement by their inertia, it becomes quite a durable and effective machine. To accomplish this in an efficient way their relative weight should be as 20 to 1 at least, that is, the crank-wheel, its shaft and connections, should be 20 times as heavy as the chisel-bar and its attachments.

The third modification, with positive chisel feed, has been built by several firms in England, and in exceptional cases, where much time and little skill is to be used in operating, it has its advantages for the heavier class of work.

The fourth class of mortising machines is the most important and useful of the reciprocating type, and from the nature of its operation and the consequent plans of construction, is free from most of the objections that apply to other machines. The distinguishing feature of the machine is the automatic arrangement for reversing the chisel, comprehending the invention of Mr. Smith, of Lowell, U.S., in regard to which we copy the following remarks, from an article by the writer, in the Journal of the Franklin Institute, in 1870:—

PLATE CI.

(TRUE ELEVATION.)



COMBINATION MACHINE.

Arranged for Boring, Mortising, Planing, Moulding, Tenoning, Sawing, &c.
Scale—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

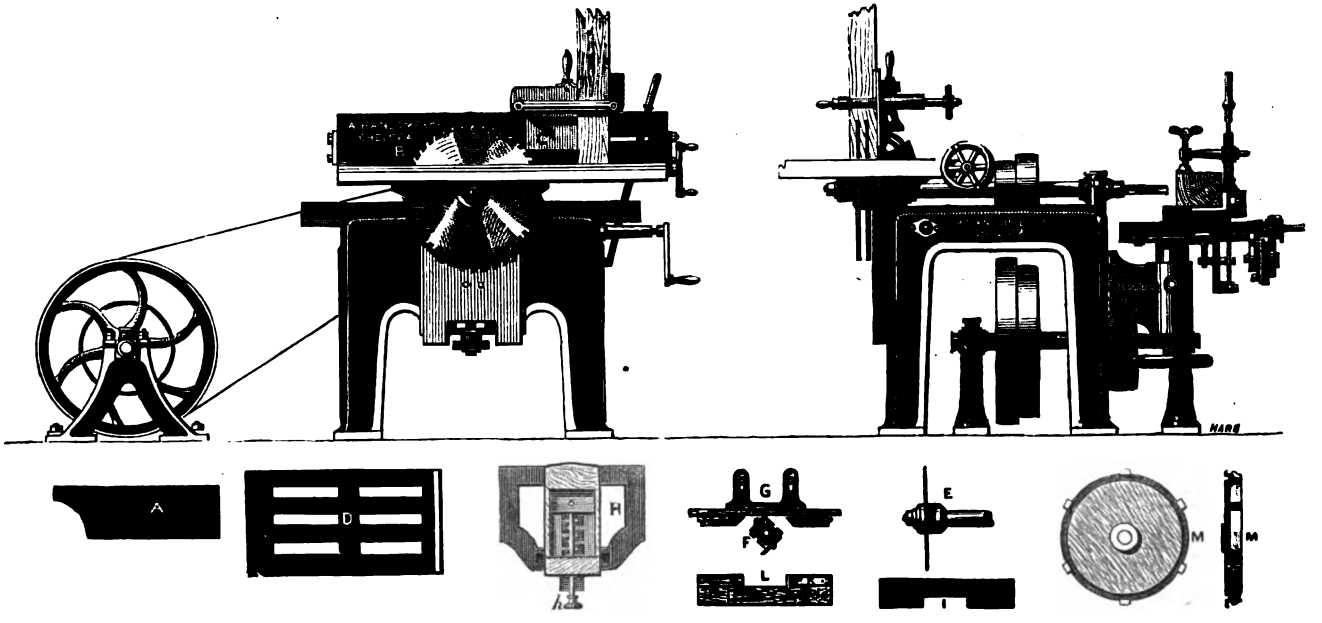
ALLEN RANSOME & Co., London, England.

"One of the most important improvements in power mortising machines which has appeared since the first conception of the machine, is the automatic reversing apparatus of H. B. Smith, patented in 1854. We say reversing device, for it is known by this name, and while it performed this function as its leading object, it also held the chisel-bar firmly while in motion, and prevented any possible deviation of the chisel by loose joints or uncompensated wear, which was hardly second in importance to reversing the chisel to form the ends of the mortise. The machines are fitted with this automatic reversing device, of which we will attempt an explanation in general terms, so far as the principle is involved. There is maintained a constant torsional strain upon the chisel-bar by means of frictional, or yielding connection, with the driving shaft, by means of a belt that 'slips' upon the pulleys, except at the instant of the rotation of the chisel. This belt is so proportioned and arranged, that while it offers no very great amount of resistance to the crank-shaft, it keeps a continuous rotary strain upon the chisel-bar, which is released by stops at each motion of the table and allowed to perform a half rotation. These stops on the machine of Mr. Smith are so arranged as to allow the chisel-bar to make one-fourth of a revolution during a movement of one inch of the table at its lower extreme, and another fourth during its ascent through the same distance, the chisel reversing its position at each motion of the table, without any care or effort on the part of the operator. This slipping or frictional contact with the continuously moving parts of the machine can be attained in various ways. A flat belt would, however, seem to be the best adapted to the purpose. Clutches having metallic faces would tend to abrade each other, and require elastic pressure. A polished metallic surface in contact with leather has, in this case, as in other places, proved itself the best combination for frictional contact. The round belt, however, wears well, and this part of the machine never gives any trouble.

"Automatic reversing devices of other forms have been applied, generally dependent upon the feed or table movement to revolve the bar—in some cases by direct contact of spiral extensions on the bar, which come in contact with a sectional nut. To revolve the chisel-bar

PLATE CII.

(TRUE ELEVATIONS.)



COMBINATION MACHINE.

For General Joiners' Work.—Arranged with various functions. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

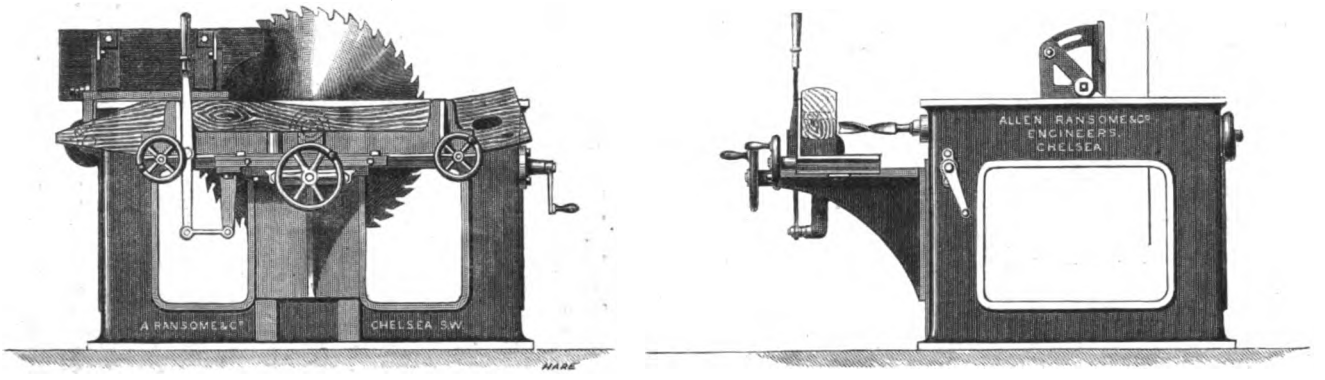
of a mortising machine by connection with the table movement must, of course, consume some share of such movement that cannot be utilized in mortising, as the chisel must be clear of the wood when reversed. To allow the bar to come in contact with any stationary part, when in motion, would only be admissible at a slow speed; while in both cases the keeping or holding mechanism that retains the bar in position when cutting, can be nothing more than a weak spring, whose force must be overcome continually in the act of reversing. These objections are only obviated by the use of some 'extraneous' force, acting upon the chisel-bar independent of the reciprocating or feeding parts of the machine, which this frictional connection with the crank-shaft gives in a very perfect manner."

Since the publication of the article quoted from, this patent has become the subject of an important suit at law for infringement, and upon the expiration of the patent, which has been extended to 1875, there is no doubt of the general adoption of this invention throughout America, at least for the class of machines to which it especially applies.

Relating to the general principles to be observed in the construction of reciprocating mortising machines for the heavier class of work, or of the three types first named, it would hardly be consistent to say much, without endorsing them as the true plan of doing such work; we, however, will add, that the ruling idea should be lightness of weight, and great strength in the reciprocating parts; deep thin sections for transverse strain, with ample bearing surfaces of hard material. The nature of the feed movement, be what it may, bears a constant and definite relation to the treadle movement. A chisel movement of 6 inches, for instance, and a treadle movement of 18 inches, with the pad, represents one-third of the force of the blow on the treadle. To break and destroy this effect on the treadle, has been the object of nearly all the various devices that have been invented and applied to such machines. Assuming the proposition that the force of the blow of the chisel-bar is communicated to the treadle in the ratio of their relative movement, except as affected by mechanism intervening, we have established a base upon which we can

PLATE CIII.

(TRUE ELEVATIONS.)



COMBINATION MACHINE.

For Boring, Sawing, Mortising, &c. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

proceed with some degree of certainty to consider the value of the various plans of connecting the two, and how far it is practicable to move the chisel down by the foot of the operator, without his receiving this reacting force against the foot.

The devices employed to form this communication between the treadle and chisel-bar are links, inclined planes, and screws. In the case of links, it may be said that for heavy work they are impracticable; the writer in an experiment on a machine built upon this principle in 1866 was compelled to introduce a "fractional resistance" to the treadle movement, to assist in absorbing the vibration and shock; the force of which had to be overcome, in addition to the other work, by the effort of the operator.

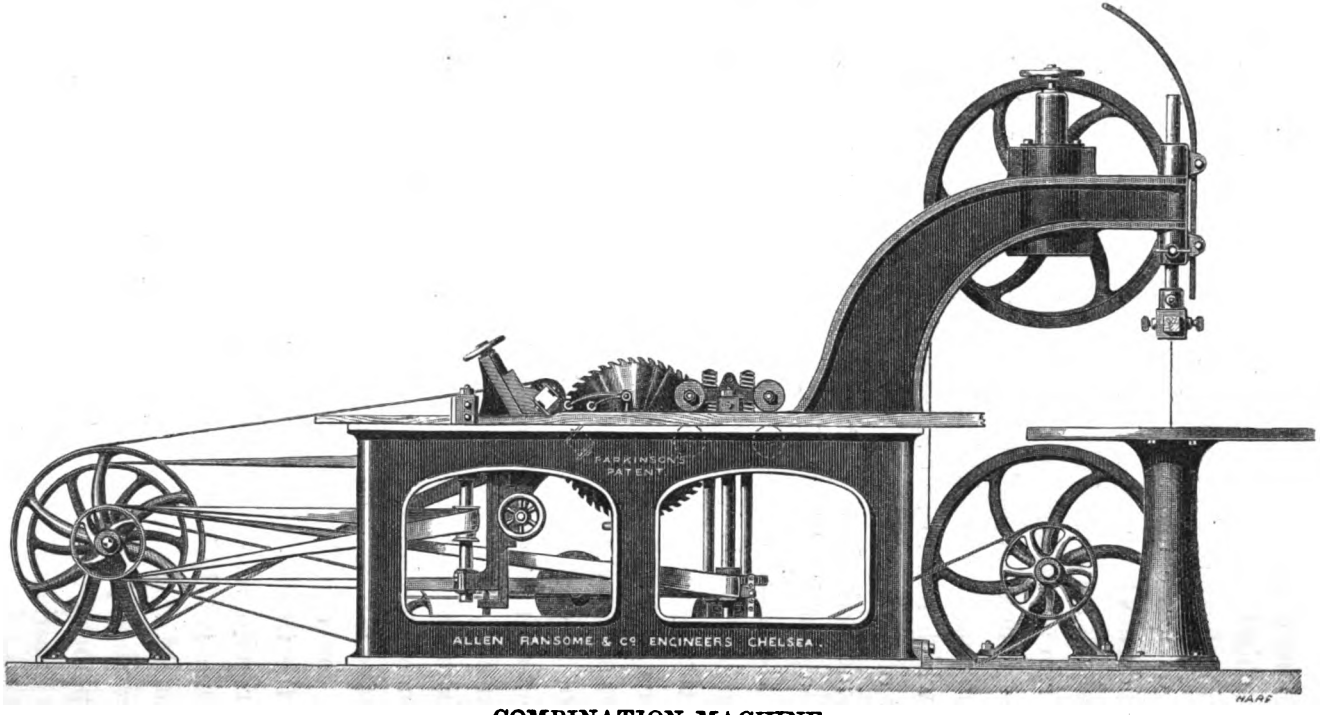
By inclined planes is meant sliding fulcrums, or, to make it plain by a familiar illustration, "forcing the feed down and withstanding the shock of the blow, by a wedge," operated by the foot; the inclination of the wedge being as the relative movement of the foot and the chisel-bar, which has been assured, as one to three. This is, of course, not the mechanism, but illustrates the principle. Under a constant strain, the resistance of the feed would be communicated to the foot of the operator as the inclination of the wedge or inclined plane; but a shock or blow is very effectually broken by the friction on the surfaces, combined with the inertia of the parts; and we find in the history of treadle-feeding machines in America that this principle of machine planes has been most successful.

To take a further advantage of this plan of operating, the writer in 1866, for experiment, introduced a compound threaded screw between the treadle and chisel-bar, one end with a right-hand and the other with a left-hand thread, the threads being of half-inch pitch. One revolution gave a movement of one inch, while the inclination of the thread represented but one-half what would have been needed with a wedge or single thread; in other words, two inclined planes were used, and their action compounded.

This question of the relation between the treadle movement and the chisel-feed movement is quite a complex one; yet it involves what we may term the whole science of the treadle-feeding mortise machine.

PLATE CIV.

(TRUE SIDE ELEVATION.)



COMBINATION MACHINE.

Arranged for Sawing, Moulding, Planing, &c. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

If the operator does not at will and by his own senses through a treadle control the action of the chisel, there cannot in the nature of things be anything gained over rotary mortising machines.

The rapidity of the work and the safety of the chisels and machine depend upon the operator *feeling its action*; and no machine has ever operated otherwise with any great degree of success.

Reciprocating mortising machines in the American market at this time require, for chisels from one to two inches wide, to make from 250 to 350 revolutions a minute, with a stroke from six to nine inches; that is, an effective stroke capable of cutting to this depth. The chisel must be returned instantly to the top of its stroke, at the completion of the mortise. The feed must be controlled by the foot, so that the operator can *feel* the action of the chisel. The feed of the carriage must be by hand, in all cases, and controlled by the will of the operator continually; no automatic action of any kind is admissible, except for reversing the chisel in the smaller class of machines.

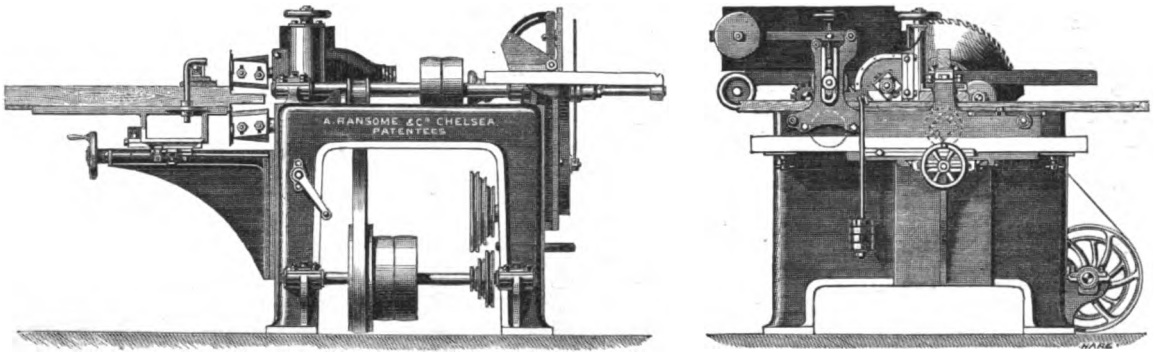
That such conditions are filled by all machines is by no means claimed. The statement is given to show the practice of the country where the greatest number of such machines are made and used, and where there are skilled operators whose business is to mortise alone.

ROTARY MORTISING MACHINES.

From careful records, kept by two large railway carriage shops, it has been ascertained that in an average class of framing, such as side and end sills, sole plates and buffer beams, the rotary mortising machines, as illustrated among the engravings, performed the work at less cost than the reciprocating machines. This, however, cannot be assumed from the time required for making the mortises alone. The gain was no doubt in a great measure due to the better facilities

PLATE CV.

(TRUE ELEVATIONS.)



COMBINATION MACHINE.

For general Joiners' Work.—Arranged with various functions. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

for handling and presenting the lumber on the rotary machines, the carriages being long enough to traverse pieces of 35 feet in length without shifting.

Granting that their capacity and adaptation will be, as with the reciprocating machine, a matter of development and improvement by a more extended use, they cannot fail to take the place of their "jarring" competitors for the heavier class of work at least.

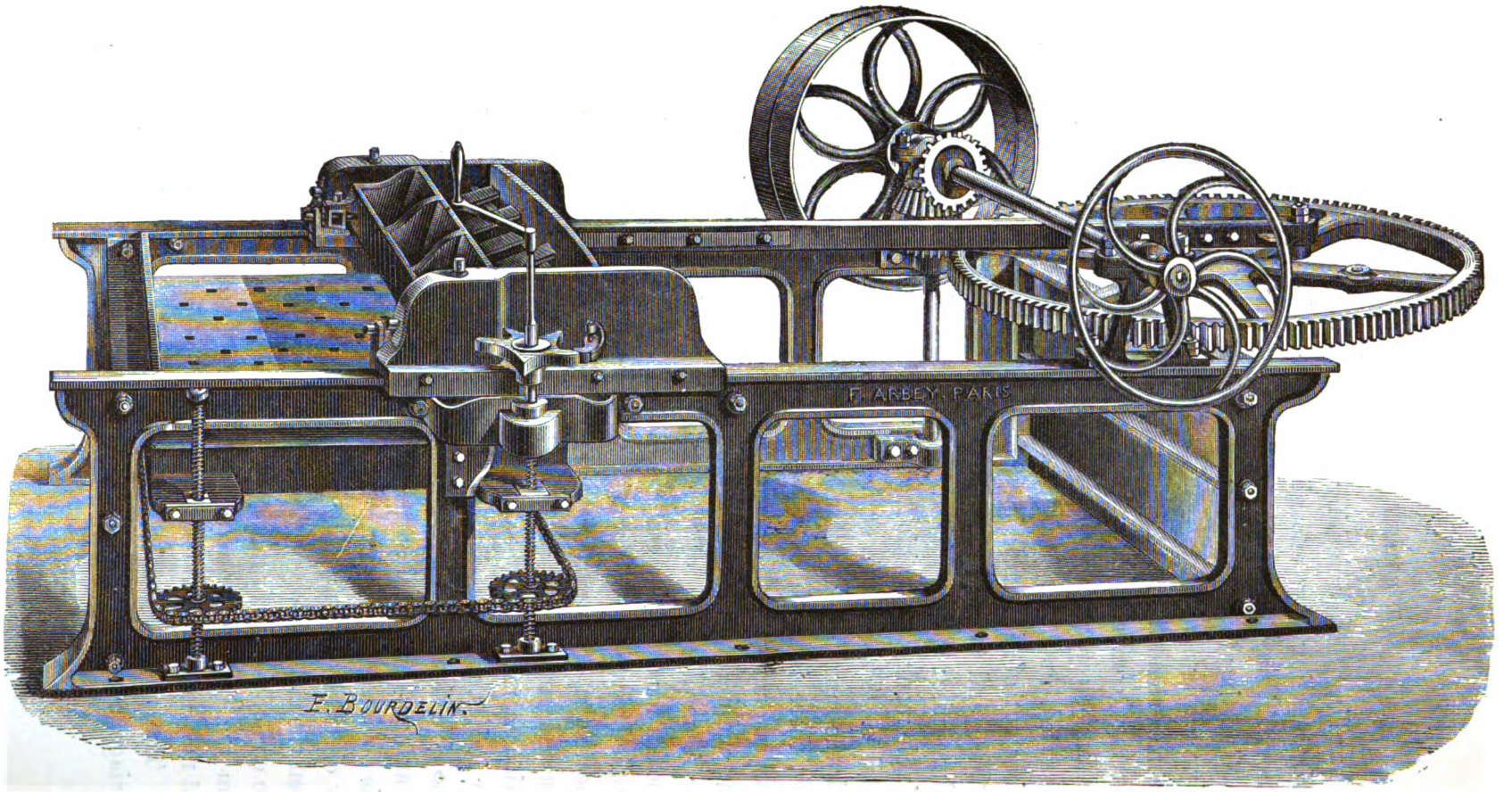
In the rotary mortising machine of Richards, London, and Kelley, illustrated, and in all such machines now in use in America, no laying out of the work is needed. A template is placed upon the machine, and the stops are set for the position, length, and width of each mortise; after which any number of pieces are worked without a single mark of any kind on the timber, and without any danger of mistakes. The boxing, or facing, can be done at the same time, and with the same tools; a plan which cannot, however, be recommended when there is much of this kind of work to do, on account of the small amount of cutting edge employed, and the consequent rapid wear and dulling of the tools.

A modification of the rotary mortising machine is used in America for chair mortising, which merits a brief notice. The cutter spindle has a vibratory motion, its frame being pivoted at one end beneath the driving pulley. The rotary motion is usually about six thousand revolutions a minute; the vibratory about four hundred motions a minute. The length of the spindles being about twenty-four inches, makes a slight curve in the bottom of the mortise, which is no objection, while the pivoting of the spindle gives an important advantage, in protecting the bits or cutters from jamming at the ends. It is obvious that with a positive reciprocating motion of the cutter, any obstruction at the ends of the mortise would break it, especially when the cutter is of small diameter, as it must be for chair mortises. The end of the cutter meets the end of the mortise, on a diagonal line from the pivotal centre of the mandril, leaving room for cuttings that may lodge in the ends.

The periphery of cutters for this class of machines that have carriage movement must be, or should be, fluted; not to give a

PLATE CVI.

(PERSPECTIVE ELEVATION.)



WOOD CUTTING AND SLICING MACHINE.

For Cutting Veneers and Wood Sheets (wood paper).

F. ARBEY, Paris, France.

cutting action, but to clear the ends of the mortises from shavings, which would otherwise lodge there and break the cutters, or by moving the timber make a tapering mortise.

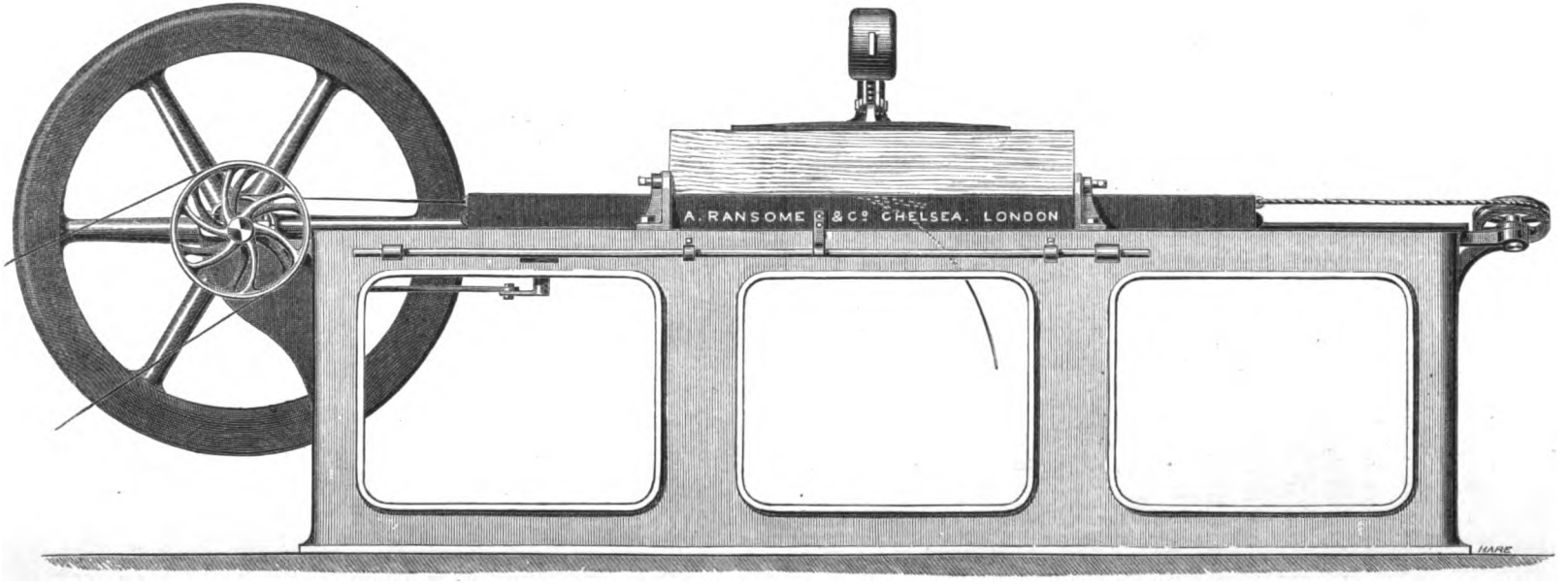
A strange fact connected with the operation of rotary mortising tools is that in operating at high speed they seem to *acquire temper*. We make this statement from facts gathered from several experiments, but do not wish to be understood as stating it as a general result, but as being contingent upon certain conditions, such as a high rate of speed, and a damp or green state of the lumber. It is, however, recommended for rotary cutters of one-half inch and less in diameter, that Stubbs' or other fine steel be used without tempering; that is, as it is found in the rod, with a kind of stiffness, but soft enough to be easily filed.

In some interesting experiments tried in 1866 with vibrating rotary cutters for mortising the throats in plane stocks, by the writer, the following facts were elicited, which will no doubt have some interest.

The machines, three in number, had a vibratory motion of 500 revolutions a minute, and a rotary motion in two of them of 7500 revolutions a minute, the other 8500 revolutions a minute. The material was hard seasoned beech wood. It was found that cutters made of forged cast steel (English bar) turned in the lathe, long enough for mortises of ten diameters in depth, soon broke; the fractures presenting evidences of crystallization; but that cutters of Stubbs' rod steel would perform the same work without breaking, and apparently without any crystallizing effect from the bending which must have taken place in cutters having such proportions. These experiments were with the spindles in a horizontal position. With the spindle placed in a vertical position, cutting at the top, so that the dust and *débris* fell by its gravity out of the mortise, cutters of *twelve* diameters in length could be worked with comparative safety; the length of the mortise was transverse to the fibre of the wood, which produced short cuttings like saw-dust, or no doubt such a depth could not have been reached in this hardest of wood. It might also be remarked that the rate of cutting was very rapid, as the speeds given indicate; that the

PLATE CVII.

(TRUE SIDE ELEVATION.)



RECIPROCATING CUTTING MACHINE.

For Scaleboards and Veneering. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

machines were operated by comparatively unskilled men, and that they have since that time continued in constant use, performing the same duty.

TENONING MACHINERY.

As a class tenon-cutting machines are quite simple when compared with those for mortising, or indeed with almost any others that like them represent a distinct class. No change of importance has been made in the tenon machine since its first application, that is to say, no change in the functions nor in the manner of operating. The mechanical construction has of course, with other machines, been since the first greatly improved, as the several engravings of machines of this class will attest.

Tenon machines for rectangular tenons are of two kinds, operating on different plans, both of which are illustrated among this general class in the engravings.

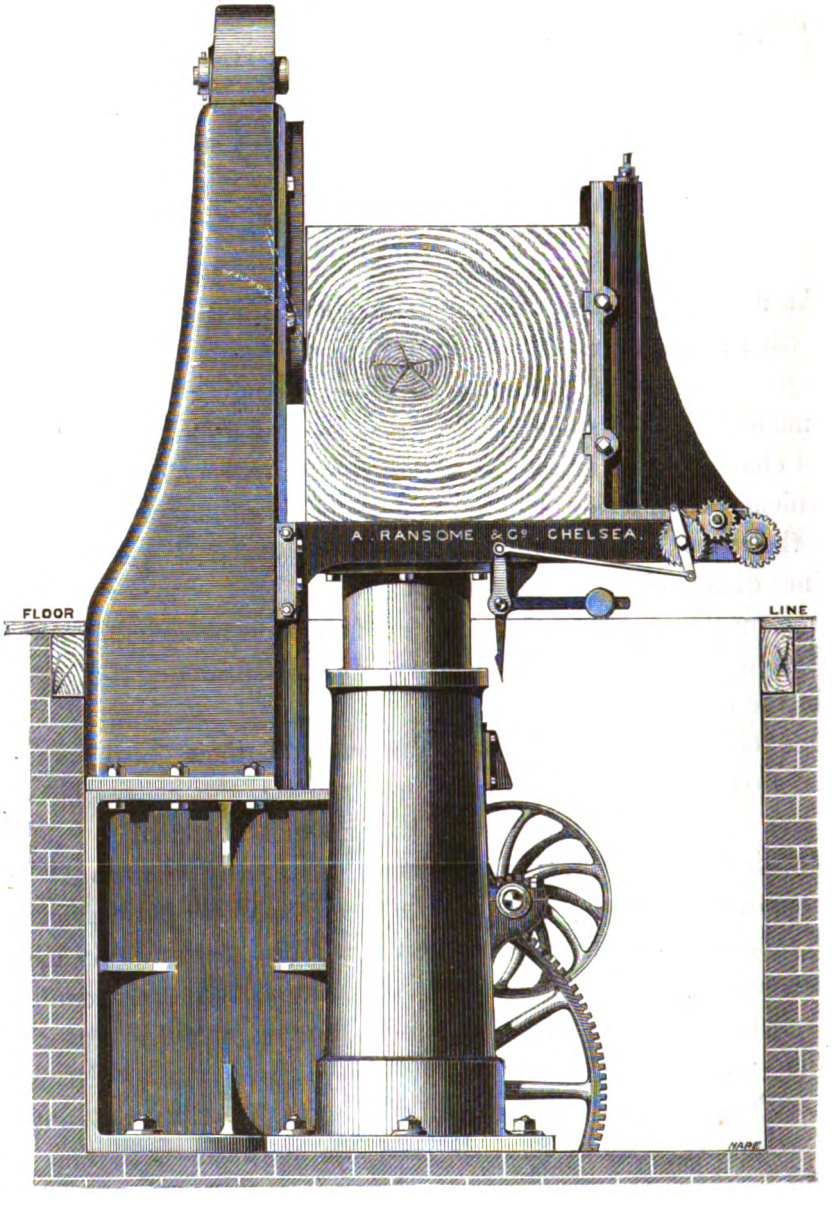
One class of machines have the axis of their cutter spindles parallel to the line of the timber and tenon; the others have the cutter axis transverse to the line of the timber and tenon.

Machines of the first class consist essentially of two or more cutter spindles, nearly parallel, with mechanism for adjusting them laterally, and a travelling carriage on which the timber is moved; with the exception of the cutter-heads, there is nothing connected with their construction or operation admitting of much notice.

The cutter-heads are as a rule made with cutters having a helical edge, originally obtained by curving the cutter; but now, by simply arranging its bed at a slight angle with the axis, and then grinding the edge to such a curve as will bring its extreme periphery or edge on parallel lines to the axis, there is nothing in the nature of the operation so far as cutting is concerned that requires this helical edge; yet it is quite important from other considerations.

PLATE CVIII.

(TRUE ELEVATION.)



VENEER CUTTING MACHINE.

Vertical movement, fixed knife, and movable carriage. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

Tenons require to be smooth, and as the cutting is transverse to the grain, this arrangement of the cutters contributes somewhat to the object. The feeding of the wood is usually by hand, and as the action of the helical edge is continuous and not abrupt, the wood can be fed more steadily.

The speed, besides, of tenoning spindles runs slower than those of most other wood-cutting machines, and the jar of cutting is thereby increased. These considerations, with the very inefficient clamping devices used, no doubt led to this arrangement of the cutters in the early machines, which has since without much change been carried out by the different makers.

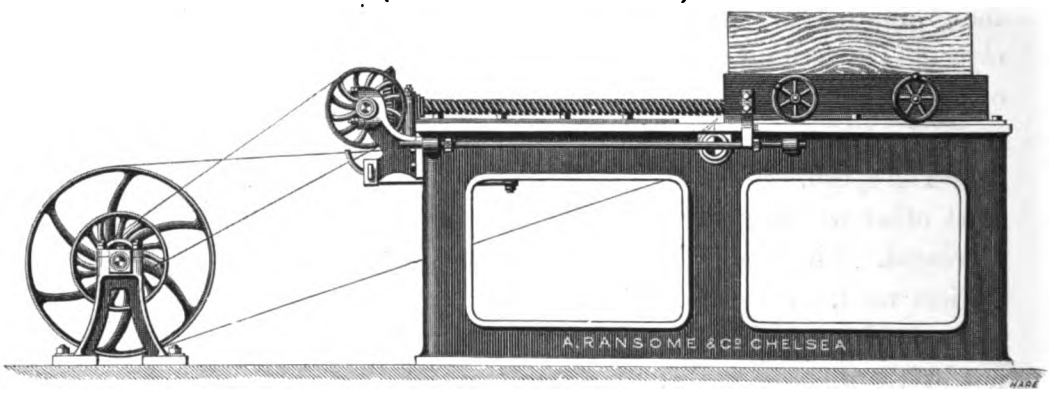
The cutter-heads of tenon machines must, from the nature of the work, overhang the spindle bearings; as the cutting is often heavy and always irregular, the spindles must be stiff and well supported. The rule before given as to overhanging spindles is applicable. The adjustment of the spindles should be both combined or independent, so as to alter either the shoulders or thickness of tenon, without the one interfering with the other.

Tenon machines with the axis of the cutters transverse to the timber, to make triple or compound tenons, are very fully illustrated among the engravings. Their especial adaptation to the kind of work indicated is, perhaps, the greatest claim to be made in their favour.

It has been stated that the power needed in wood cutting is mainly expended in cross-cutting the fibre. Granting this, it naturally follows that the cross-cutting should be done at as few intervals as possible, leaving the greatest possible share of the work to be done by the splitting process. Now these two types of the tenoning machine may be said to represent opposite extremes in this regard; the first cross-cutting at but one end of a wide cut, while the other cross-cuts the whole width of the cut, and at intervals close enough to form shavings transverse to the fibre. The objection as to the extra amount of power needed is, however, a secondary matter, if considered alone; and for short tenons in heavy timber, and where more than one tenon is to be made, the advantages of the last

PLATE CIX.

(TRUE ELEVATION.)

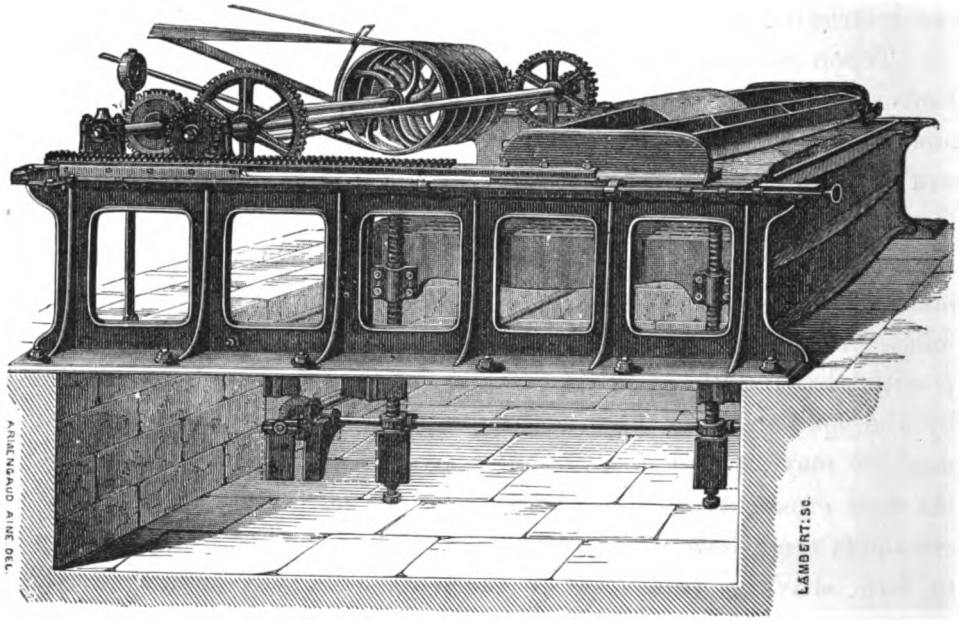


JOINTING MACHINE.

With rotary cutters. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

(PERSPECTIVE ELEVATION.)



RECIPROCATING CUTTING MACHINE.

For Scaleboards, Veneering, and Sheet Wood.

F. ARBEY, Paris, France.

arrangement are so obvious that they need not be questioned. In some of the largest railway carriage works in America this system of tenoning has for several years been in use with good results.

The inconvenience of adjustment compared with the other kind of machines unfits them for what may be called jobbing uses, and it is only when a large number of duplicate pieces are wanted that there is much gained in their use.

Tenoning was in times past, and is yet to some extent, done with saws instead of cutter-heads; an expedient generally adopted from convenience rather than policy. There is in no case any good reason *for grinding or cutting wood into fine dust* to remove it, and all operations that have this result must be wrong, both in the use of unnecessary power and in the rapid dulling and wear of the cutting edges.

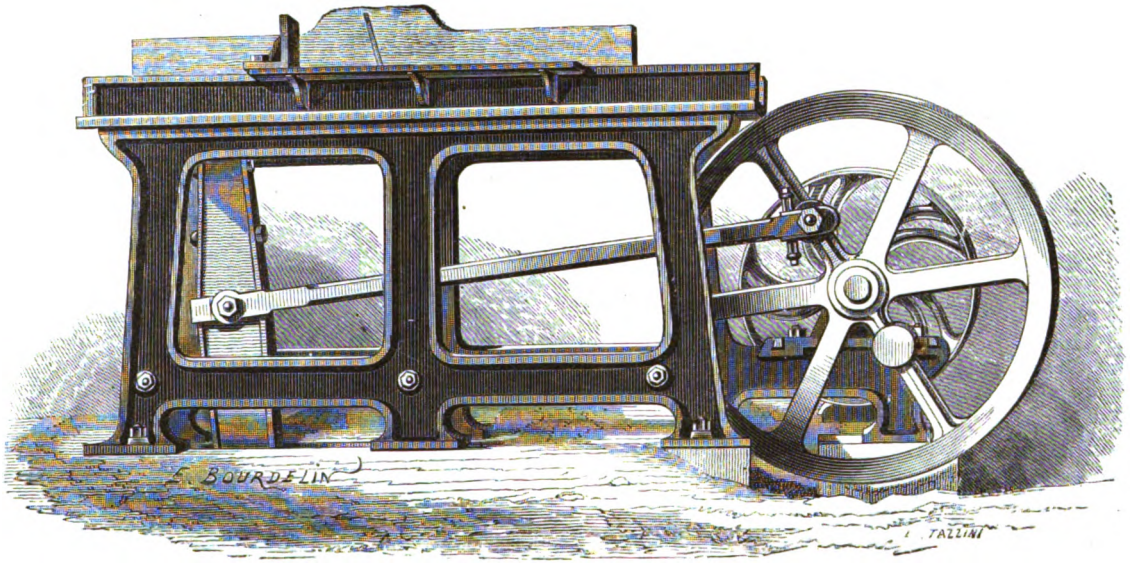
SHAPING MACHINERY.

Having now consecutively followed the leading operations in wood conversion, through sawing, planing, mortising, and tenoning, we come to shaping, under which head can be classed all operations involving irregular lines, or, to state it otherwise, all operations that involve other than straight or circular lines. This class of wood-cutting machines are of recent origin when compared with those for working straight or cylindrical forms, and yet from the endless adaptation that the principle is capable of, it comprehends a greater variety of machines than is directed to either sawing or planing.

Down to about the year 1830 all operations in wood work that involved irregular lines were without exception performed by hand. No machines were known, or if known, were not used, previous to the introduction of those built under the patent of Boyd or Blanchard, noticed in the beginning of this treatise. This patent, although dated 1820, failed for a term of twenty years at least to disseminate any

PLATE CX.

(PERSPECTIVE ELEVATION.)



RECIPROCATING PLANING AND JOINTING MACHINE.

For Smoothing the Ends of Pieces and Making Accurate Joints.

F. ARBEY, Paris, France.

ideas of irregular cutting by machinery, and it would be in fact no exaggeration to say that even at the present time the general principles upon which such machines operate are but imperfectly understood. We of course do not mean to say that such machines are to be properly and intelligently arranged by the builders, but that their operation is popularly appreciated as a kind of mysterious one that does not come within the regular sphere of mechanical laws.

There was in fact such an air of improbability about the cutting out of shoe lasts, gun-stocks, &c., by machines at the beginning, that the impression has not yet passed away. Among those unacquainted with mechanics, and we might include a great share of those who have studied only special branches of mechanics, a machine is always associated in the mind with rotary motion and true curves, or rectilinear motion and straight lines. This is the less strange when we consider that aside from economizing human force, the great object of machines and the distinction between machine and hand manipulation may be explained by saying, that *machines act in true geometrical lines with almost unlimited force and speed.* "Hand operations" *are not guided in true geometrical lines, and are limited in power and speed.*

Hence the machinery for irregular forms, although governed by the same laws, presented the idea of an anomaly to the mind.

The mechanism involved also contributes to this impression; it is of a character more complicated than that for straight lines or curves, so much so, indeed, that in some cases the plan of operating is with great difficulty explained to the unskilled.

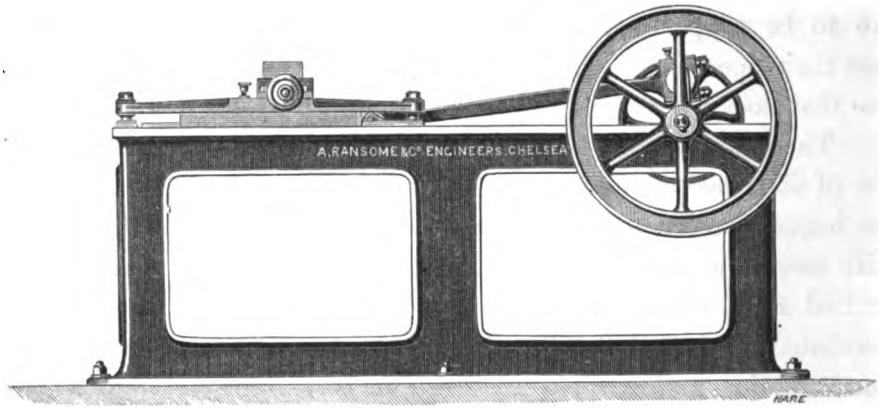
Shaping machinery, in the sense in which the term is here employed, comprehends turning machines for irregular forms, carving machines, and machines operating in one plane only; such as the moulding tables with right and left spindles, that are illustrated among the engravings.

The operation of all these machines can be described in a general way as "working from a pattern," duplicating forms already produced, from which and by which the action of the tools is directed.

The part in contact with the model can be termed a guide, between which and the cutting tools, or the blank itself, there is

PLATE CXI.

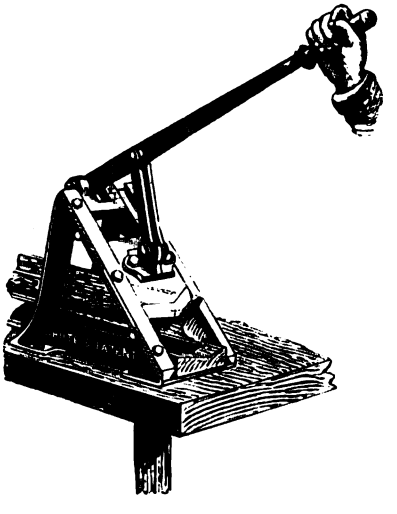
(TRUE ELEVATION.)



RECIPROCATING CUTTING MACHINE.

For Lucifer Match Splints. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.



CUTTING AND PARING MACHINE.

coincident movement. In all the various modifications of machinery for shaping, we find the same mechanical equivalents, although for the better understanding of them they can be divided into two classes; those that adjust or move the tools, and those that adjust or move the material, so as to receive the action of the cutters on its different configurations.

In machines for turning lasts, gun-stocks, spokes for wheels, &c., they are about equally divided between the two arrangements, if we include the spoke machines made in America, in which, as a rule, the material is moved to the cutters. For carving and the more delicate operations, the tools are adjusted to the forms, or, as is sometimes the case, the adjustment is divided between the material and the cutter spindles; the one moving in a horizontal plane and the other vertically.

In shaping machines, operating in one plane only, for what we will term "edge milling," the rule is to move the material.

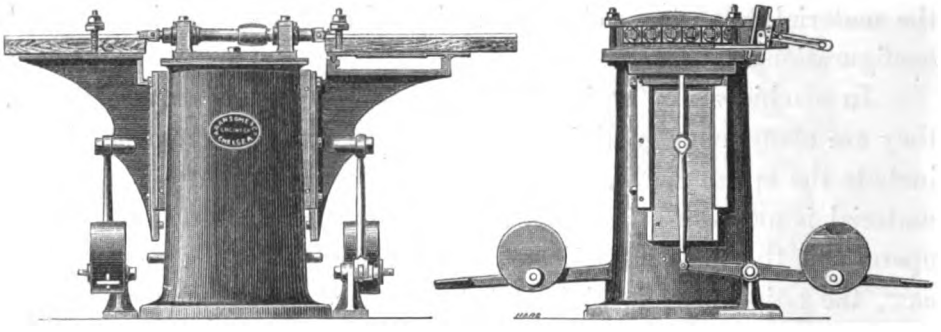
In regard to the class of machines first named, the diversity of practice in their arrangement is no doubt owing to some other reason than varying conditions in the work performed; for the analogy between the operation of turning gun-stocks, spokes, shoe lasts, &c., is complete. The same machine will in fact perform these several operations, and needs but little special modification to adapt it directly to either. Yet we find in America the "Blanchard Lathe," as it is termed, built with the spindles, patterns, gearing, in fact nearly all the details mounted in a swinging frame, which vibrates to give the irregularities of the work.

There are many exceptions to this, among which may be named the very excellent lathes in use at the Springfield Armoury for gun-stocks; yet the prevailing plan for spoke turning is with the vibrating spindle frame.

In a former place there was given a rule relating to the relative movement between the parts of machines, one that for brevity and simplicity recalls the historian's celebrated chapter on the "Snakes of "Iceland" — "move the one that is easiest to move." Were this simple and obviously correct rule followed in the arrangement of

PLATE CXII.

(TRUE ELEVATIONS.)

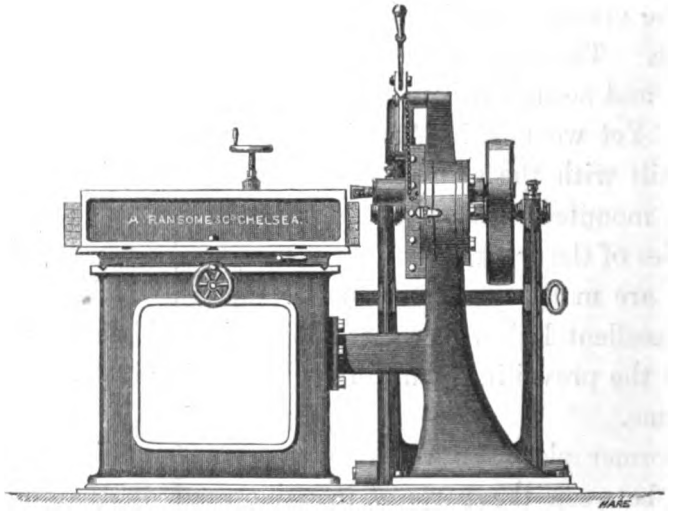


MULTI-SPINDLED DOVETAILING MACHINE.

For Packing-cases and Rectangular Boxes. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

(SIDE ELEVATION.)



SINGLE SPINDLE DOVETAILING MACHINE. (Designed by Ramsbottom.)

ALLEN RANSOME & Co., London, England.

the American spoke turning lathes, the cutter-head would certainly perform the vibration needed to produce the elliptical sections.

That the common arrangement is one of those errors growing out of an engineering mistake is sufficiently attested by the fact that none but the cheaper machines are arranged in this manner, and the better lathes used in the armouries and for most other uses than spoke turning have the vibrating cutter-heads. It might, too, be cited, that all European makers arrange them in this manner, as will be seen in the machines illustrated by the engravings.

To follow this system of duplication through the extended and various applications made to wood shaping would exceed the limits allotted to it here, and would besides lead into detail not intended in this treatise. It would in fact constitute a volume by itself, with illustrations of machines that would in number quite equal the whole number here given.

BORING MACHINERY.

Boring machines, although in their nature quite simple, admit of endless modification in their adaptation, which relates continually to the presentation of the material, or to the adjustment of the auger, which is the same thing.

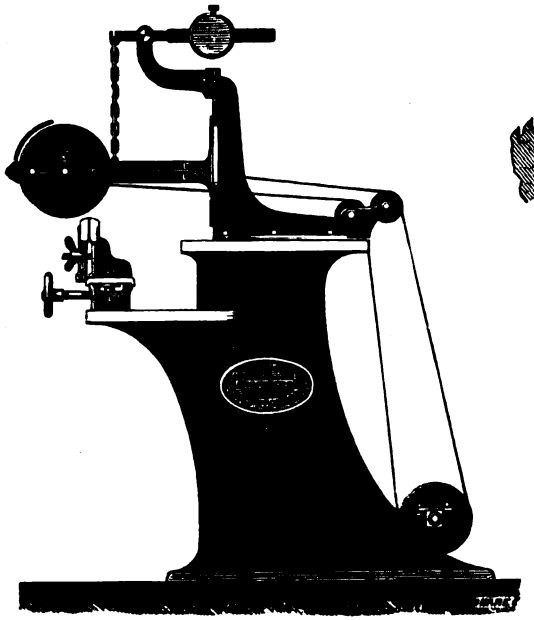
Having only rotary action and comparatively slow speed, they present but few of the difficulties that attend the designing and arrangement of most wood-working machines.

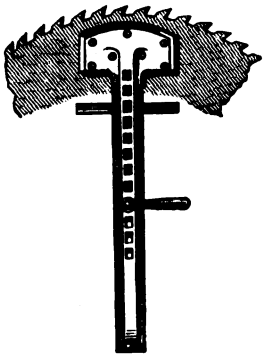
Implements for boring, so far as their edges are concerned, are governed by the rules laid down in the article on "Cutting," and need no further notice. The spirals for removing shavings have been the subject of much experiment, and various forms of "bits" have from time to time appeared, each with special claims to urge, but it is safe to assume that the old flat twisted shank is now, as it has been for a quarter of a century past, the standard auger.

A very ingenious auger is in use in America for boring long

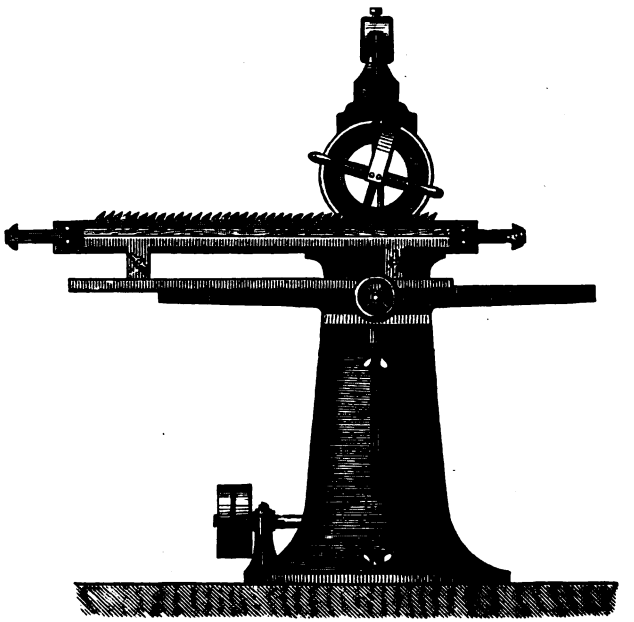
PLATE CXIII.

(TRUE ELEVATIONS.)





VICE FOR CIRCULAR SAWS.



MACHINE FOR SHARPENING SAWS.

By means of emery wheels. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

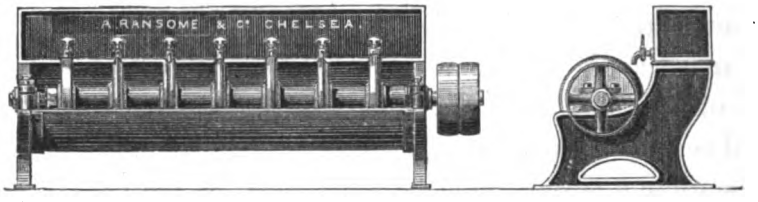
wooden pipes, and other work that requires great truth, which may in time reach a more extended application.

The auger is surrounded by a thin metallic shell, in which the volute portion runs loosely. This shell or tube is turned true and straight; it follows and guides the auger, the shavings or cuttings being carried out through its interior. The lips or cutters of the auger are expanded at the end, so as to cut a hole just large enough for the passage of the tube. The shavings are carried out with the greatest ease and certainty, owing to the smooth interior of the tube, which is of course quite different from the rough sides of the hole in the wood. Pieces of ten or more feet in length are bored to diameters of from one and one-half to four inches, with the greatest facility and at but little cost.

In the designing and arrangement of boring machines, the main object to be observed is adjustment of the material, or of the augers, so that they can be brought to different positions with the least expenditure of time and effort. To consider the matter in a general way, we will assume that a compound movement is required, transverse to and longitudinally with the timber. The longitudinal movement, being of a long and indefinite range, is best accomplished by moving the material; the transverse movement, on the contrary, being short and less used, is best accomplished by a lateral adjustment of the spindle. The longitudinal adjustment having to carry the weight of the material, has to be accomplished for the heavier class of work by mechanism that will increase the power of the operator and diminish the motion, so as to secure accurate adjustment. The lateral adjustment of the boring tools should also be done by hand, as no special power is needed to perform it.

For machines that are arranged to bore holes on one line only, the lateral motion of the spindle becomes an adjustment only, as distinguished from a continuous movement at will. The spindle, or table, when "set," remains fixed during the time of boring the holes in one line. Questions of horizontal or vertical spindles; range of movement; hand, lever, or treadle feed, &c., are of too special a character to admit of any useful consideration here.

PLATE CXIV.

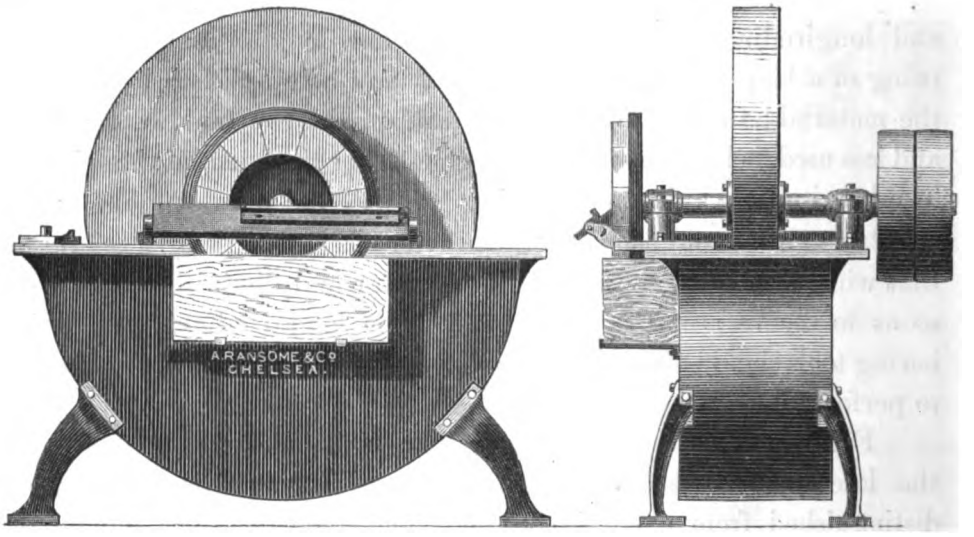


GRINDING MACHINE FOR MOULDING-IRONS.

With seven stones.

ALLEN RANSOME & Co., London, England.

(TRUE ELEVATIONS.)



GRINDING MACHINE FOR WOODSHOPS.

With face and periphery stones. *Scale*—$\frac{1}{24}$th, $\frac{1}{2}$ inch = 1 foot.

ALLEN RANSOME & Co., London, England.

DOVETAILING MACHINES.

A history of the persevering efforts of inventors to produce successful machines for dovetailing, and the various machines constructed for the purpose, would make a book in itself. It might be added that if the trials and disappointments were included, the book would partake of the character of a romance. It would be uncharitable to say that there is no need of such machines, it would be wrong besides; but to say that the usual estimate of their value is wrong, and that inventors have as a rule proceeded without considering the true conditions in the matter, is a safe assumption.

In a former part of this treatise some views were given, relating to invention and labour-saving, which, if applied to dovetailing, will not leave a very flattering balance in favour of the machines.

That dovetailing for perforated work, chests, packing cases, &c., can be done by machinery better and cheaper than by hand, is not disputed. In ship carpentry, too, where the drawers are set athwartship on the centre line as a base, an adjustable machine is a great improvement over hand cutting.

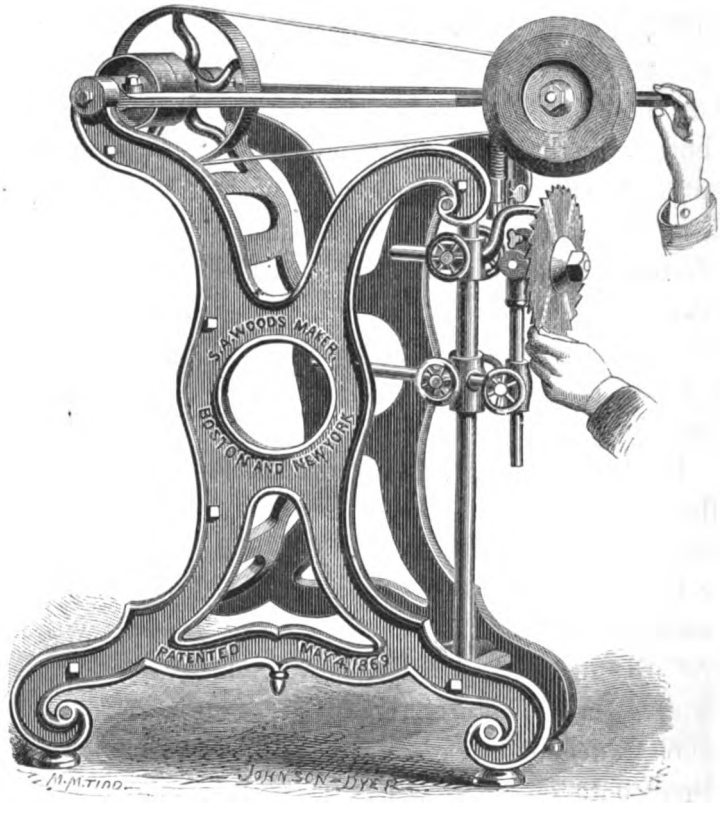
Three-fourths of all the dovetailing done, however, is on rectangular drawers for furniture and cabinet work; and it is with reference to this branch it must be especially considered.

In furniture manufacture, the fronts of drawers must be fitted by the bench workmen; each front is a special piece, and any machine directed to dovetailing comes at once in contact with this trouble. A system of duplication is impossible in an operation which of all others most needs it; of course the "fronts" can all be duplicates as to dovetailing, but must be numbered and kept distinct in handling.

An expert workman will dovetail in soft wood, and drive together twenty-four drawers, six inches deep, in six hours. Supposing there are five pins to each corner, this represents over 1600 "cuts," not counting shoulders, which are with machines cut at the same time

PLATE CXV.

(PERSPECTIVE ELEVATION.)



GRINDING MACHINE.

For Sharpening Circular Saws.—With emery wheels.

S. A. WOODS, Engineer, Boston, U.S.A.

as the sides of the pins. This represents a hand performance that is certainly a very perfect one, and if analyzed according to the general rules and laws that govern such operations, leaves no great margin for machine saving.

From the usual stand-point of inventors, of course such a proposition would be wrong. It is common to look for a *chance* result, that shall bear no relation to hand labour, and capable of doing an unlimited amount of work; but all such things are illusory. Every machine and every operation must come within the scope of certain laws, which, if understood, will enable us without experiment to predicate, with a great degree of certainty, what can be done with machines in any case.

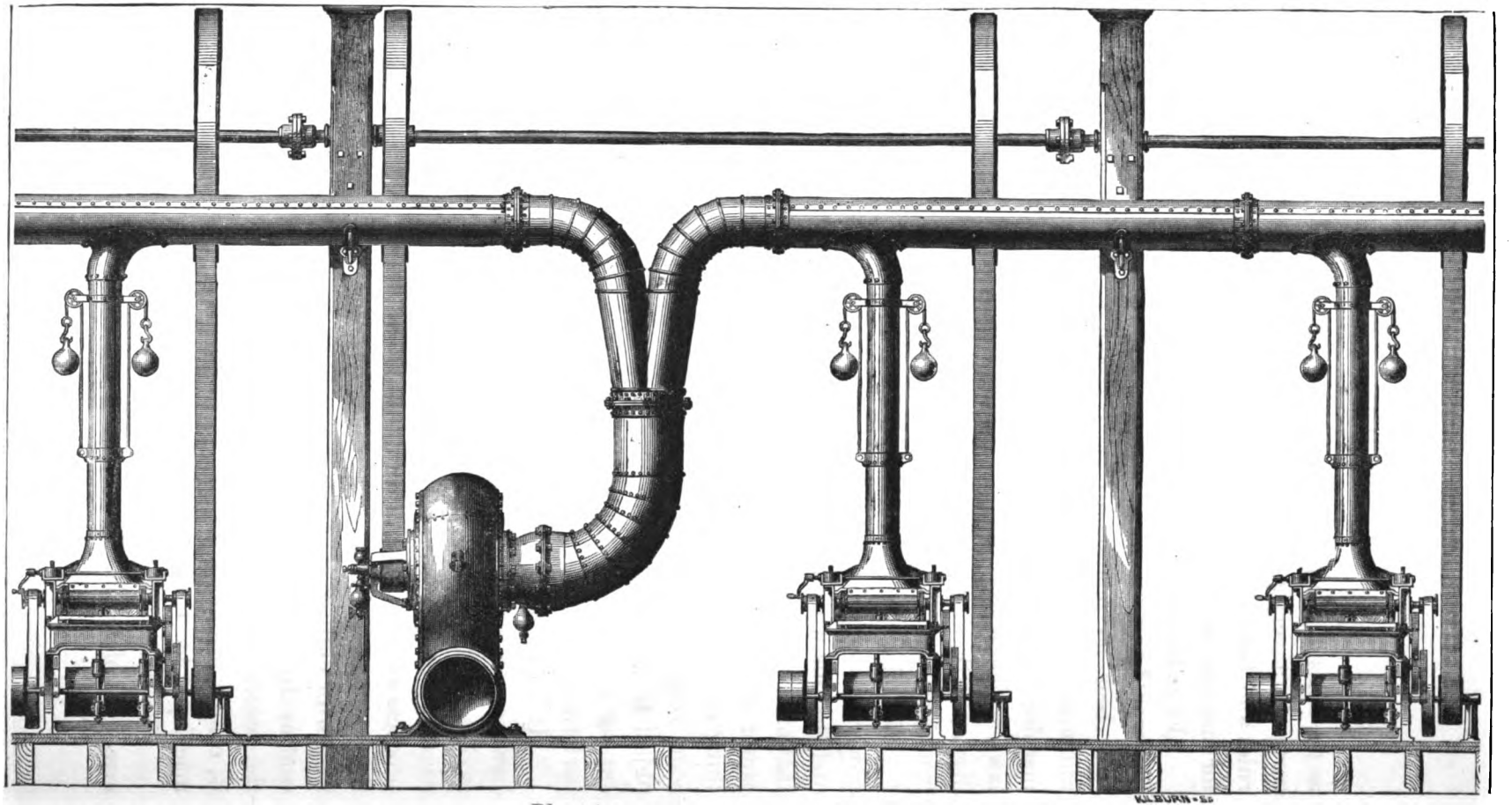
We find in hand-dovetailing that the operator does not lack power; his physical force is sufficient to guide and operate the tools, and that his work is not restricted from this cause; here then is lacking that most important condition that tends to labour-saving by machines; power is not wanted, as in planing, sawing, and boring, it is something else. Accuracy is not wanting in the hand work, for it is in some respects better than machine work, for drawers at least. The object to which the machines are directed must be the adaptation of cutting edges in many positions, and with a rapidity superior to hand performance.

It is difficult to convey in words the idea intended; the converse, however, is that operations in which machinery effects the greatest saving, are those where much power can be used, where long cutting edges can be applied, and where few adjustments are needed during the progress of the work. We need hardly say that dovetailing presents the reverse of all this: but little power can be applied, a very limited length of cutting edge used, and the adjustments are incessant and continually require the attendance of a skilled operator. We leave the matter with this statement of the general principles that govern it, calling attention, however, to how fully the past history of such machinery has confirmed these laws that govern wood cutting.

We may mention, however, as an exception, the dovetailing machines of O. H. Evarts, of New York, which have lately been

PLATE CXVI.

(TRUE ELEVATION.)



Plan of removing Shavings from Wood Factories.

B. F. STURTEVANT, Boston, U.S.A.

adopted by Mr. Thomas Davidson, Constructor and Engineer, United States' Navy, at the Philadelphia yards. Their performance, and the very excellent work effected with them, warrant a belief that they stand in advance of previous machines, and for many uses will supersede hand labour, especially for other than rectangular corners, as this is a class of work rather difficult to execute by hand, yet it is quite simple when performed on the machine.

CUTTING MACHINES WITH DIRECT ACTION.

Of this class of machines some good examples are given among the engravings of machines for cutting, veneering, scaleboards, matchsplints, &c.

The economy of these machines, as compared with sawing for thin boards, drew attention at an early period in England, and a great variety of such direct cutting machines have been made, adapted to nearly every use where they could be applied.

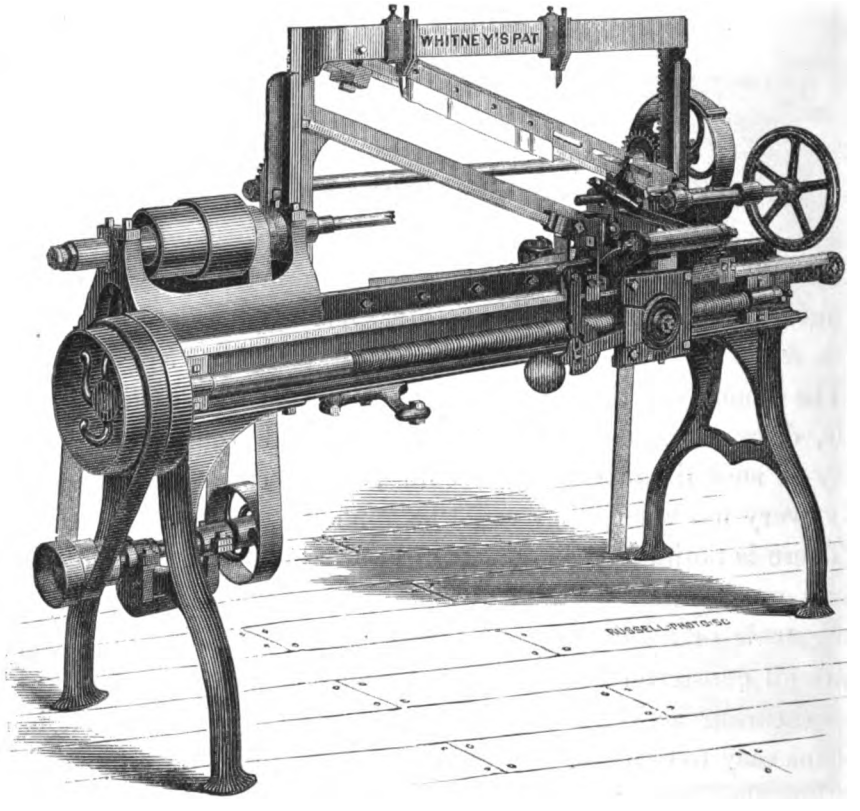
There is nothing in the mechanism of such cutting machines that requires much attention here; they involve the old proposition of moving tools or moving material, and with this unimportant distinction are all constructed on about the same general plan; the knives have a shearing action, which in cutting has an influence that is by no means easy to explain, not that there is anything mysterious about it further than that the effect is greater than we could expect from theoretical deductions.

The wood has, as soon as it is cut, to bend outward and accommodate itself to the bevel of the knife; making an angle that shatters the fibre and destroys the integrity of the wood. This effect increases with the thickness of the scales cut, and has a limit for unsteamed wood of about one-eighth of an inch in thickness. When the wood is boiled in water, or steamed, it becomes sufficiently flexible

PLATE CXVII.

EXTRA-CLASS TURNING.

(PERSPECTIVE ELEVATION.)



AUTOMATIC LATHE.

Adapted for Ornamental Turning.—Has a shearing or smoothing cutter, seen behind on the reciprocating frame.

B. D. WHITNEY, Winchendon, U.S.A.

to be cut into shingles, and the staves of what are termed "slack barrels" in America, used for flour, lime, salt, &c.

The heavy machine of M. Arbey, illustrated, is used for cutting "wood paper," a very thin grade of veneering used for covering the walls or panels of the rooms of houses, having a thickness of only about one-eightieth of an inch. There is, as yet perhaps, but little to develop in these cutting processes so far as machinery is concerned; the great economy of the plane will, however, keep the matter before the world, and there may perhaps be something developed in connection with the cutters, or in the treatment of the wood, that will lead to its more extended application.

Having now treated in a general way of what can be termed the regular operations in wood cutting, anything further would lead into a class of machines which are more or less special; and of which the little that could be said in this treatise would have neither value nor interest.

As machines assume a special character they need more minute description, and when we consider that wood-cutting machines consist largely, and more than any other class, in special modifications, the reasons given for not entering upon it will be quite satisfactory.

In conclusion we note some things of general interest, pertaining to wood manufacturing.

PNEUMATIC CONDUCTORS FOR SHAVINGS.

The rapidity with which a new thing is adopted is generally a true indication of its merit, or at least of its money-saving value.

To apply this rule to the system of clearing the shavings from wood manufacturing establishments by induction-fans, or blowers, as it has lately come into use in America, we must grant its importance at once, for there is no improvement, involving the same amount of change and expense, has ever been so generally introduced in the same length of time. Although but three or four years since the

first application of this system, it is now the exception to find a first-class mill without it.

The large planing mills of the Lake district in America, from being places full of rubbish, dust, and shavings, have as if by magic been cleared of everything, and present an appearance of cleanliness, neatness, and safety from fire, that is worth what the conductors cost, to say nothing of the economy otherwise effected.

Among the engravings is given a view of a planing floor, fitted with the apparatus of B. F. Sturtevant, Engineer, of Boston, U.S., which gives a correct idea of the arrangement as usually made.

A large induction-fan is placed at some central point and connected, either by wood or sheet metal pipes, with the machines of all kinds that create dust or shavings, either by means of hoods that come down over the cutter-heads, or by enclosing the whole machine-frame and exhausting the interior.

A sufficient pressure, or rather vacuum, is maintained, to lift the heaviest shavings, which with the dust are drawn through the pipes into the fan, and there expelled by pressure, and carried to the furnace or elsewhere, as may be wanted.

In a point of economy it is hard to institute a fair comparison. The old plan of clearing the shops by hand only related to the removal of shavings after they had accumulated, while the fine dust from sand-papering and other machines of the same class was cleared by special blowers.

The new system accomplishes all, and does not allow any accumulation whatever; it besides leaves the whole floor room available for storing and handling material, and conduces to the comfort and health of the workmen.

In regard to the relative cost of simply removing the shavings it is represented, no doubt, very nearly in the difference between the cost of a man's labour compared with the same amount of power in a steam-engine. Judged from the nature of the operation, that of walking back and forth, carrying a sack or basket, this estimate is perhaps a correct one, supposing the man to be continually employed at this one thing.

BELT CONTACT AT HIGH SPEEDS.

That speed should be an element in estimating belt contact is apparent in looking at the spindle pulleys in wood-cutting machines. The degree in which belts are affected by centrifugal force in running at high speed is dependent upon the tension, weight, and flexibility of the belt and the diameter of the pulley. At 5000 feet a minute, with belts of ordinary harness leather, running on pulleys six inches or less diameter, the amount of contact is not more than three-fifths of what would be shown in a diagram, and is often much less. Coupled with this, however, is the strange fact that the tractive force does not seem to be as constant as the amount of contact. That the pressure on so much of the surface as has contact is increased by the belt "lifting," is unquestionably the case, but it hardly accounts for the want of proportion between the power transmitted and the amount of contact. This matter is mentioned as an experimental fact and merely to stand as a reason for saying that the width of the belts, need not be predicated directly upon the pulley contact for high-speed spindles.

For spindles having unusually high speeds, the writer has found belts of cotton webbing to be preferable. Such belts, if closely wove and of the best material, will, when waxed, be found to have a high tractile power and wear well, while their comparatively light weight avoids their lifting from centrifugal force.

The convexity of pulleys to keep belts central should be sufficient for the purpose and no more. It is difficult to account for the practice of many builders of wood machines, especially in England, who give a degree of convexity to pulleys that interferes with the contact and tends to the distinction of the belt, unless both pulleys have their faces the same, a thing impossible in the case of shifting belts. Without entering into an examination of the laws and conditions that govern the matter, the following rule is given.

For pulleys from two to twenty-four inches face, the convexity

should be from one-eighth of an inch to one-sixteenth of an inch to a foot, graduated inversely as the width of the faces; for pulleys of narrower face the convexity can be slightly increased.

This is quite sufficient to govern the running of belts, and a necessity for more can safely be construed as a fault in the position of the shafting.

MACHINE OPERATORS.

Considering the amount of special knowledge required, its diversity, and the length of time needed to acquire it, there is no purely mechanical trade that ranks above that of machine hands, who operate wood machines. In America they are, as a rule, men who have learned wood work to begin with; generally as joiners, and then gathered some knowledge of machine fitting and millwrighting. In the principal lumber-working districts their pay is greater than is given to any other class of workmen. Some first-class establishments pay as high as sixteen shillings per diem to their leading machine men.

In machines driven to their full capacity, the cost of skilled attention is not the element that most affects the profits, it is the character and amount of work turned out; the length of time during the day that the machines are idle, that is the main point.

The operator in a planing mill must, or should, understand the whole theory of carpentery and joinery; he should carry in his head by memory thousands of standard dimensions, with the names and catalogue numbers of catalogue mouldings of every form; he must understand machine fittings so as to direct and make repairs, and must besides be strong and healthy to stand the wear and anxiety incident to his calling. These things are reverted to here, to urge the necessity of a higher grade of skill in operating wood machines; they are not, as has been elsewhere stated, to supplant skill, but rather to assist it: to add the element of physical force to the power of the

mind. The attendant should always have as much to do in the operation of the machine as he can attend to. The rule should be, instead of crowding automatic functions into machines, to stop them as soon as the operator can dispense with them.

To again revert to wood manufactures in America, it is a fact well known that the cheapest production is always by the highest-priced workmen, or, as it should be stated, by the most skilled and interested workmen; for as a rule, and as the result of a general law, wages bear a pretty constant ratio to what they produce. Future progress in wood manufacture in all parts of the world is dependent upon the two conditions, improvement of machines and the improvement of the men who operate them; to whom we must look for the greater share of those practical ideas of the improvement of machines, especially in details, that cannot be arrived at through other sources.

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